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See Illustrated Advertisement Page 100, Jan. 28, 1921.

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See page 17, Jan. 13. 9947

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See Advertisement page 77.

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See Advertisement, page 26. 9353

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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

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See Advertisement page 64, Jan. 13. 2402

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See Full page Advertisement page 68, Jan. 6.

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See Full Page Advt., page 69, Jan. 6.

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LIFTS. 9453
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1, Great James Street, Bedford Row, London, W.C.1.
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See Advt. page 90, Jan. 13
Steam & Pneumatic Power Hammers
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9741

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TENDERS.

CORPORATION OF DUBLIN.

Tenders for the Cast-iron Pipes, Valves, Castings and other necessary Fittings required for the Valve Tower of the new Reservoir at Roundwood, Co. Wicklow.

Notice is Hereby Given that

the TIME for sending in TENDERS is EXTENDED to the 23rd JANUARY, 1922.

By Order,
JOHN J. MURPHY,
Town Clerk.

Town Clerk's Office,
Exchange Buildings,
Lord Edward Street,
Dublin. 13th January, 1922. T 165

CORPORATION OF CALCUTTA. WATERWORKS EXTENSIONS CONTRACTS, 1921.

The Corporation of Calcutta are prepared to receive

Tenders for :—

CONTRACTS I to VI, consisting of the SUPPLY and LAYING in a prepared trench of THIRTY MILES OF RIVETED STEEL PIPE in the following sizes :—60 in., 54 in., 51 in., 48 in., 42 in., 36 in., and 33 in.

Plans can be seen and copies of Specification, Tender, etc., obtained on or after January 30th, 1922 :—

IN ENGLAND, from the Consulting Engineers, Messrs. St. George-Moore & La Trobe-Bateman, M.M.Inst.C.E., 91, Victoria Street, Westminster, S.W. 1, and

IN INDIA, from J. R. Coats, Esq., B.Sc., M.Inst.C.E., Chief Engineer to the Corporation of Calcutta, Central Municipal Offices, Calcutta.

The sum of £5 or Rs. 75 respectively, will be charged for each set of four copies of the contract documents, which sum will be returned on receipt of a *bona fide* Tender, prepared in triplicate.

Two copies of all Tenders, from wherever emanating, to be delivered at the offices of the Consulting Engineers in London, at or before Twelve noon, on March 16th, 1922, when they will be officially opened in the presence of such Tenderers as care to attend. The third copy to be despatched by registered post on or before the same date, addressed to the Chief Engineer, Corporation of Calcutta, Central Municipal Offices, Calcutta.

Tenders to be in sealed covers and superscribed "Corporation of Calcutta, Tender for Steel Mains."

The Corporation do not bind themselves to accept the lowest or any Tender.

Tenderers may submit separate Tenders for alternative proposals.

B. V. RAMIAH,
Secretary to Corporation.

Calcutta,
January, 1922. T 152

THE ROHILKUND AND KUMAON RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for the Supply of :—

MATERIALS for the Construction of 100 Four Wheeled Covered Goods Wagons.

400 AXLE BOXES for ditto,

as per specifications to be seen at the Company's Offices.

Tenders addressed to the undersigned, and marked "Tender for Wagons," or as the case may be, are to be lodged not later than Noon, on Friday, the 10th day of February, 1922.

For each Specification a fee of 10s. will be charged, which cannot, under any circumstances, be returned.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order of the Board,
E. A. NEVILLE,
Secretary.

237, Gresham House, Old Broad Street,
London, E.C. 2.
18th January, 1922. T 201

DUNFERMLINE CORPORATION WATER WORKS.

CONTRACT No. 3.

DUPLICATION OF GLENSHERUP MAIN.

The PROVOST, MAGISTRATES AND COUNCILLORS of the CITY AND ROYAL BURGH of DUNFERMLINE are prepared to receive

Tenders for Laying about

THREE MILES of CAST IRON PIPES, chiefly 15 in. in diameter, together with the Construction of Incidental and Relative Works, between SALINE and CRAIGLUSCAR.

The Plans may be seen on and after Tuesday, 17th January, at the Office of the Engineers, Messrs. Crouch & Hogg, C.E., 31, Lynedoch Street, Glasgow, from whom copies of the Specification, Schedule of Quantities, and Form of Tender may be obtained on payment of Two Guineas, which will be returned to everyone sending in a *bona fide* Tender.

Sealed Tenders, marked "Dunfermline Corporation Water Works, Contract No. 3," must be lodged with the undersigned not later than Saturday, 4th February.

The Corporation do not bind themselves to accept the lowest or any Offer.

ANDREW SHEARER, Town Clerk.
City Chambers, Dunfermline,
11th January, 1922. T 183

DUNFERMLINE CORPORATION WATER WORKS.

CONTRACT No. 3.
(SUPPLY OF CAST-IRON PIPES.)

DUPLICATION OF GLENSHERUP MAIN.

The PROVOST, MAGISTRATES AND COUNCILLORS of the CITY AND ROYAL BURGH of DUNFERMLINE are prepared to receive

Tenders for Supplying about

THREE MILES of CAST-IRON PIPES, chiefly 15 in. in diameter, together with sundry Pipes of Smaller Sizes.

Particulars of the Pipes required may be had on application from Mr. R. Muir Morton, Burgh Engineer, Dunfermline, on and after this date.

Sealed Tenders, marked "Dunfermline Corporation Water Works, Contract No. 3 (Supply of Pipes)," must be lodged with the undersigned not later than Saturday, 4th February.

The Corporation do not bind themselves to accept the lowest or any Offer.

ANDREW SHEARER, Town Clerk.
City Chambers, Dunfermline.
11th January, 1922. T 187

Tenders are Invited by

the GOVERNMENT of NEW SOUTH WALES for the CONSTRUCTION of the SUPERSTRUCTURE and SUBSTRUCTURE of a CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR from DAWES POINT to MILSON'S POINT, embracing a main span of 1600 ft. in the clear, centre to centre of main piers, or 2000 ft. centre to centre of anchor piers. The total length of bridge included in tender is 3816 ft., centre to centre of abutments. The deck of the bridge is to include four lines of railway, and a roadway 55 ft. wide, between main trusses; and cantilevered outside the main trusses on the western side, a footway 15 ft. wide, and on the eastern side a motor roadway 18 ft. wide. Copies of specification, including plans, general conditions, and schedule of quantities may be obtained on application to the undersigned.

To give any information required by Tenderers, Mr. J. J. C. Bradfield, Chief Engineer, will be in London during June and July, 1922, address care of the undersigned.

Tenders in accordance with the specification must reach the Under Secretary for Public Works, Sydney, not later than 31st October, 1922.

AGENT-GENERAL,
FOR NEW SOUTH WALES.
Australia House, Strand, London, W.C. 2.
December, 1921. T 34

COUNTY BOROUGH OF SOUTHAMPTON.

NEW PUMPS, CORPORATION WHARF.

The Corporation invite

Tenders for Dismantling

Existing PUMPS, and SUPPLYING and ERECTING THREE NEW 18 in. CENTRIFUGAL PUMPS at the Corporation Wharf, Chapel, Southampton.

Particulars may be obtained at the Borough Engineer's Office Southampton, upon production of the Borough Treasurer's receipt for a deposit of £1 1s.

Deposits will be returned after the Council have dealt with the Tenders, to those who have submitted *bona fide* Tenders.

Sealed Tenders endorsed "Tender for Pumps," must be delivered at the Town Clerk's Office by Twelve o'clock at Noon on the 4th February, 1922.

The Corporation do not bind themselves to accept any tender.

R. R. LINTHORNE,
Town Clerk.
16th January, 1922. T 161

GREAT SOUTHERN & WESTERN RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply and

DELIVERY of about 160 tons of STEELWORK for Ten Short Span Bridges.

Specifications and drawings can be obtained from Mr. F. J. Sides, M.Inst.C.E., Chief Engineer, Great Southern & Western Railway, Inchicore, Dublin, on payment of £2 2s. which will be refunded on receipt of a *bona fide* Tender.

The Directors do not bind themselves to accept the lowest, or any Tender.

Tenders must be delivered on or before the 13th February, 1922, to the undersigned.

ROBERT CRAWFORD,
Secretary.
Kingsbridge Terminus, Dublin. T 199

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely :—

	Fee for Specification.
No. 1. Helical and Volute Springs.	£1
No. 2. Mild Steel Bars, Sections, &c. (For Bridge Renewals)	£1
No. 3. Mantles for Lamps	5s.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Helical and Volute Springs" or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 31st January, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2, London.
18th January, 1922. T 202

APPOINTMENTS OPEN.

Secretary-Director Required,

preferably with knowledge of Engineering, to control London Office of provincial manufacturing company owning rapidly-increasing business. Audited accounts show net profit of 56 per cent. p.a. on invested capital after payment of Directors' salaries. Investment £2000. Salary £320 p.a. plus dividends. Open to Solicitors' and Accountants' investigation.—Write, BOX 1355, Sells, 167, Fleet Street, E.C. 4. T 184

Managing Director Required

for an old established Engineering works in the North of England, employing about 150 hands, doing special and general work. Splendid opening for a young energetic man of ability. Salary £500 to £600 p.a. together with bonus on profits. Investment £2000 to £3000. Strictest investigation on both sides.—Address, T 193, Offices of Engineering.

Works Manager.—A Small

but Well-established Factory near London REQUIRES a thoroughly Experienced WORKS MANAGER, who has specialised on the production of apparatus of the typewriter class. He will have entire charge of the factory, but will have no reponsibility for sales. Only those experienced in the actual post-war production of this class of apparatus need apply; the position will carry a good salary and exceptional prospects for a really first-class man. Applications, which will be treated as confidential, should state age, experience and salary required.—Address, T 180, Offices of Engineering.

BURMA RAILWAYS.

THREE ASSISTANT ENGINEERS.

The Directors are prepared to receive

Applications (by letter only)

from duly qualified CANDIDATES for APPOINTMENT as ASSISTANT ENGINEERS in their WAY and WORKS DEPARTMENT in India.

Candidates must be between 22 and 28 years of age, active, of good physique, with a thorough knowledge of instrument work, and well trained in ordinary engineering knowledge. They must have had at least three years' training in a recognized Engineering College and not less than one year's practical experience. Preference will be given to Associate Members of the Institution of Civil Engineers, or those who hold an exempting degree.

Salary.—Rs.550, rising by annual increments of Rs.50 to Rs 1100 per calendar month without exchange compensation allowance. Commencing salary if aged 24 or below, Rs.550, but if more than 24 and the selected candidate has had War Service, the commencing salary would be Rs.50 per month more for each year over that age up to a maximum of Rs.650. Men wounded in the War would be acceptable provided they are fit for the work.

Terms.—A three years' agreement in the first instance, first class free passage to Burma and home again on satisfactory termination of services.

The selected candidate will be required to pass a strict medical examination by the Company's Consulting Physician before final appointment.

Applications, giving a full record of candidate's career in chronological order (stating their age, and whether married or single), and showing where they obtained their general and technical education and practical experience as Assistant Civil Engineers, with dates in each case, must be addressed to the undersigned not later than Tuesday, 7th February, 1922.

W. HOME, C.I.E.,
Managing Director.
109, Gresham House, Old Broad Street,
London, E.C. 2.
Dated 17th January, 1922. T 185

Assistant [illegible]d by Con-

SULTING E[illegible] Westminster. Must be well educated and [illegible]htsman capable of arranging lay-outs [illegible]lectric and other plant. Knowledge [illegible] and ventilating desirable but not [illegible]ddress, enclosing copies (not originals [illegible]onials with particulars of qualificati[illegible]rience and stating age and salary requi[illegible]r t[illegible] Thursday, January 26th, T 192, [illegible]

The Fuel Ec[illegible]

of the Federation d[illegible] been requested to RECO[illegible] HOUSE SUPERINTENDEN[illegible] brewery in the London distri[illegible] have had experience in the super[illegible]shire boilers and the control of firemen[illegible]tent to make the tests necessary to [illegible]nt working. Replies stating age, [illegible]rience and salary required, should be addressed [illegible] ECONOMY DEPARTMENT, Fed[illegible] British Industries, 39, St. James's Stre[illegible] S.W. 1.

Wanted, Experienced M[illegible]

NERY SALESMAN for India by Ca[illegible] Firm of Engineers, Public School boy prefe[illegible] Five-year agreement. Pay commencing Rs. 6[illegible] a month. No married men will be considered.—Write, Z.A. 571, c/o Deacons, Leadenhall Street, London. T 196

Wanted, Engineer for Blast

Furnace Plant. Must be experienced with Electric Power.—Address, stating age, experience and salary required, T 37, Offices of Engineering.

Smart Junior Estimating

ENGINEER REQUIRED by London firm, with practical experience designs and sales correspondence. Steam, gas, electrical plant and centrifugal pumps.—Address, with full particulars, age and salary, T. 186, Offices of Engineering.

Engineer Required for Esti-

mating and negotiating contracts and carrying these through to completion. Public School and University man preferred. Practical training essential and some knowledge of design of centrifugal and turbine pumps desirable. Should be experienced and competent salesman with good connection, whose chief duties would be to promote energetically the sale of machinery of this character.—Apply, giving full particulars with age and salary required, to W. H. ALLEN SONS & CO., Ltd., Queen's Engineering Works, Bedford. T 168

Wanted, Powerhouse

ENGINEER with thorough experience of construction, maintenance and repairs of steam turbines up to 3000 Kw., condensers and auxiliaries; also good theoretical knowledge of station economy, operating practice and some experience of high tension generators and switchgear. Three years' contract for tropical Brazil at attractive salary. Previous experience abroad desirable. Single man preferred, not under 35 years of age.—BOX 916, c/o Judd's, 97, Gresham Street, E.C. 2. T 191

Deputy Resident En-

GINEER REQUIRED by the Government of Nigeria for Lagos and Apapa Harbour Works, for two tours of 12 to 18 months' service, with possible extension. Salary £1200 per annum, rising by annual increments of £50 to £1400 per annum, with a Duty allowance of £240 per annum. Free quarters and first-class passages. Liberal leave in England on full salary. Candidates, not over 45 years of age, must be duly qualified Civil Engineers, and have had a wide experience on an Engineer's or Contractor's staff in the actual construction of harbours and dock works, both by contract and departmentally.—Apply at once, in writing, giving age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/Nigeria 11281. T 171

Civil Engineer Required

by the Government of Zanzibar, for one tour of 20/30 months' service as an Assistant Engineer in the Public Works Department, with a prospect of permanency. Salary £400 per annum, rising by annual increments of £20 to £500 per annum, and thence by annual increments of £25, to £600 per annum, payable locally in rupees at 15 rupees to the £. Free quarters and first-class passages. Liberal leave in England on full salary. Candidates, single and under 35, must have had good practical experience on roads, buildings, and other public works, and preferably have passed the A.M.I.C.E. or an equivalent exempting examination. Apply at once, in writing, giving age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/Zanzibar, 11288. T 170

Civil Engineer for Rail-

WAY CONSTRUCTION REQUIRED by the Government of the Gold Coast, for two tours, each of 12 to 18 months service, with possible extension. Salary £600 per annum rising by annual increments of £30 to £720. Outfit allowance of £60 is paid on first appointment. Free single quarters or an allowance in lieu, and first-class passages. Liberal leave in England on full salary.

Candidates, preferably single, age 25 to 35, must be fully qualified Civil Engineers who have had practical experience on Railway Survey and Construction. Apply, at once, in writing, giving age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/Gold Coast 11366. T 169

Draughtsman Wanted, experi-

enced in the design and execution of pneumatic systems for collecting and conveying wood shavings and other material. State age, experience and salary expected.—Address, PNEUMATIC, Wm. Porteous & Co., Advertising Agents, Glasgow. T 195

Wanted, First-class Design-

ING DETAILER; also first-class DETAILER, for light Structural Work. Must be accurate, careful, fast and capable of taking complete charge of job. Test will be given. Good wages to good man.—Address, stating age, experience and salary, T 163, Offices of Engineering.

THE DEVELOPMENT OF AUTOMATIC TELEPHONY.

THE rise in the cost of labour in recent years has directed increased attention to the labour-saving which may lie in the use of automatic telephony, and as a consequence great progress has been made in its practical application during the post-war period. We have described the system of automatic telephony adopted in this country in considerable detail in the past, but a brief summary of recent advances will no doubt be of interest.

The main advantage of automatic switching as against manual operating will be clear from the following considerations:—

FIG. 1. SUBSCRIBER'S AUTOMATIC TELEPHONE INSTRUMENT.

Service.—In a large city a considerable proportion of the traffic passes over junction circuits, and as the system grows the number of telephone exchanges increases and the junction traffic becomes more complex. It is a fact well known to telephone engineers that the increased complexity in junction traffic leads to decreased accuracy in operating, and it is therefore evident that the natural development of a big telephone system must increase the difficulties incidental to the giving of a good service. The time of operating a call (*i.e.*, the process of setting up and taking down a connection) when that call is completely operated within one exchange is approximately 15 seconds, but the operating time rises to about 40 seconds when the call passes over junction lines. It has also been found that operators can handle traffic less reliably when the subscribers numbers contain five digits than they do when the number has four digits, and consequently it has been necessary to impose upon a manual exchange an artificial limit of 10,000 lines, although this may be quite insufficient to meet the normal development of a congested district. This limitation leads to the development of junction traffic which in the manual case results in the handling of calls by a sequence of operators.

An operator's efficiency is greatest when she is afforded a full traffic load at her own position. During the slack times of evenings and Sundays it is necessary to compensate for the reduction of load on her own position by arranging for her to take charge of several adjacent positions. The conditions of operating are then comparatively unsatisfactory and the operator's load and grade of service are bound to suffer.

As against these considerations the time occupied in establishing a call on an automatic system lies between 6 seconds and 16 seconds, and the release of such a connection is effected in less than half a second, making a total operating time with full allowance for the case of a large city of something less than 17 seconds. The junction traffic incidental to machine switching adds nothing to the time of operating a call, and the growth of the system with its increase of junction complexity does not have an appreciable lowering effect on the grade of service. It has therefore become evident to all telephone engineers, that a growing and complicated system will give a rapid and accurate service in future years only if machine switching be adopted.

Administration.—Looking ahead, it is clear that the growth of the system combined with the trying nature of manual operating will produce conditions under which it will be progressively more difficult as the years pass to obtain an adequate supply of operators. It also has to be remembered that this difficulty becomes specially acute in times of war, when it is essential that the use of the telephone shall not be impaired. The average service of an operator is about four years, and even with an intensive system of training, several months must elapse before she can take up actual work, and she rarely becomes expert in less than eighteen months. There is therefore very great difficulty in maintaining an uninterrupted supply, under all circumstances, of an efficient operating staff, and the necessity for doing so imposes a great burden upon the telephone administration. A large operating staff also involves an extensive managerial force who are concerned with the adjustment of operators' loads, the arrangement of duty attendances, the substitution of staff during sickness and vacation, the provision of transport facilities during emergency, the provision of meals and the upkeep of operators dining and rest rooms, and, of course, the payment of operators' wages.

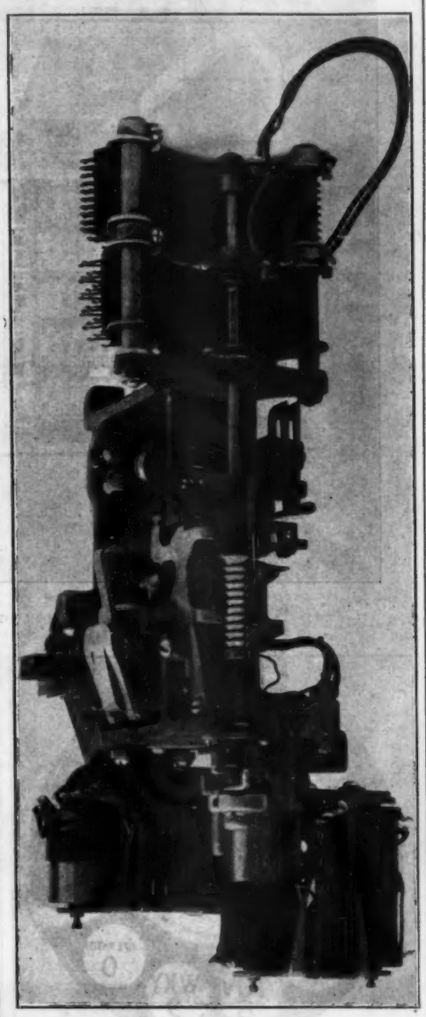


FIG. 2. STEP-BY-STEP SELECTOR.

It is clear that a satisfactory automatic system eliminates the bulk of these disadvantages, and the force necessary for maintaining the switching mechanism is very little more than that required to maintain the plant necessary for giving a manual service.

Accommodation.—The housing of a manual telephone exchange demands the provision of a long, narrow, well-lighted room for the accommodation of the switchboard. The finding of suitable sites in large cities, particularly in the congested areas, is difficult, and it is a great relief to the administration to know that in the case of automatic equipment a much wider range of shape, in site and building, is practicable.

Finance.—From the service administration and accommodation points of view, there can be no question as to the superiority of automatic over manual telephone equipment, but as regards finance, the situation may change from time to time. Automatic equipment has been more recently developed and is more complex than manual plant. It is therefore naturally more expensive in first cost at present. As the two classes of plant do not differ appreciably in cost of upkeep, the economies are in the main determined by the saving in operating costs as compared with the outgoing charges for interest and depreciation on the excess capital. The position from a financial point of view will in the future depend very largely on the economies in first cost that may be attained by the organisation of factories, particularly with regard to mass production. The parts used in the construction of automatic plant are largely press products, and much may therefore be expected in this direction.

The operation of step-by-step automatic exchanges which have been in use in this country for a number of years will no doubt be generally familiar. Briefly, the operation consists in the control of a machine at the exchange by a special calling device or dial fitted on the subscriber's telephone. Fig. 1, annexed, is an illustration of a telephone equipped with a dial. The subscriber in calling a number, places a finger in the appropriate hole on the front of the dial, revolves the front plate until the finger reaches a finger stop, then withdraws the finger and the dial returns to normal. This is repeated for each digit of the number required. When the movable plate of the dial returns to normal under the influence of a coiled spring, the line is disconnected a number of times corresponding to the digit; thus in calling "7," the line will be disconnected seven times, and if the number "7362" is required, four trains of impulses or disconnections are given, each train corresponding to one of the digits.

The normal operation of the dial gives a pause between the trains sufficient to influence a change-over device at the exchange, and so switch out one piece of apparatus and substitute another. The apparatus involved in the setting up of a connection at the exchange is known as a selector. In the example quoted, the first selector picks out a group of contacts corresponding to the seventh thousand group and finds an idle junction line into that group. The change-over device then substitutes another selector within this group which finds the third hundred in the seventh thousand, and so on until eventually the connection is established to subscribers' line "7362." This is the elementary basic idea of mechanical switching devices at telephone exchanges; an actual selector switch is illustrated in Fig. 2, annexed. As explained above, the switch when taking a call selects a free line to a similar switch in the next rank having access to the 100, 1,000, or 10,000 group corresponding to the digit dialled. When this digit is dialled the central shaft is stepped vertically so that its wipers are opposite the corresponding row in the 10 rows of bank contacts, and then immediately the shaft automatically rotates and stops when the wipers connect to the first disengaged contacts in the row. Each switch absorbs one digit of the number called until the last switch in the train is reached. This switch absorbs two digits, viz., the units and tens of the called number. A series of these selectors mounted in racks in an automatic exchange is shown in Fig. 3, on the next page.

As its name suggests, the step-by-step system accepts the impulse from the subscriber's dial, and by the direct action of ratchets and pawls, operates

the selectors in synchronism with the operation of the dial. There, is, however, another type of automatic switching plant that is driven by motor, and as it is impossible to maintain similarity of speed as between the subscriber's dial and the driving motors, it is necessary to provide for the acceptance and storage of the impulses from the dial on a special apparatus known as a sender. At the appropriate time the motor-driven apparatus utilises the stored impulse and the destination of the call is thereby controlled. Two selectors of this type are illustrated in Fig. 5, on the opposite page. The bevelled wheels on the left are geared to wheels on a permanently revolving motor-driven shaft, so that the horizontal spindles are continuously rotating.

The process of the call is as follows:—The subscriber lifts his receiver and listens. He is automatically connected to an idle sender circuit, and is informed of this fact by hearing a characteristic note in his receiver. He now dials and the impulses are stored on a quick-action, direct-operating sender equipment. A selector of the type shown in Fig. 5 is now automatically connected to the sender equipment, and the vertical brush carriage rotates under the action of a magnetic clutch formed by the vertical and horizontal discs shown in the figure. The brush carriage consists of 10 sets of triplicate brushes, each set being provided with a latching device. The sender equipment controls the rotation of a trip spindle shown on the left of the figure so that a finger is projected at the required point, and on the rotation of the brush carriage, the latch, in passing this finger, is released, throwing the brushes of that particular level into contact with the bank visible behind the brush carriage. The brush carriage rotates until an idle line to the next group is found. In the main, the system of switching from one rank of selectors to another is fundamental, as described in the step-by-step system. On the release of the connection the magnetic clutch is again energised and the brush carriage is driven past the vertical roller shown on the right. The function of this roller is to restore the latch which was released when the brush carriage passed the trip spindle. The brush carriage is then returned to its home position as indicated in the figure. An installation of this type of selector is shown in Fig. 6, on the opposite page.

In connection with stored impulse systems it is necessary to have a piece of apparatus that will control the sequence of operation and so ensure that the mechanism performs the appropriate function at the right time. The device provided for this purpose is known as a sequence switch, and is shown on the extreme right-hand side of Fig. 5. This switch is driven by a magnetic clutch operated at the appropriate moment. On the vertical spindle are fitted cams with projections and depressions so arranged that 18 sets are electrically opened or closed in any of 18 positions. It will be seen that there is, therefore, a very wide range of circuit conditions that can be satisfied by the operation of the sequence switch, which is, briefly, a mechanically-operated relay having 18 sets of contact springs.

It may be of interest now to state the elaborations of the automatic system that have been proposed for the application of mechanical switching apparatus to the conditions of a large city.

In a small town in which all the subscribers are served by one exchange, it is comparatively simple to change over from manual to automatic working. The new equipment is installed and automatic telephones are provided at the subscriber's office. At a pre-determined time on a specific date, the subscribers are instructed to use the dial on their new telephone and at the same time, by well-known method, the whole of the lines are transferred from one exchange equipment to the other. Usually such a transfer takes place without hitch, and if the subscribers follow the instruction cards provided with the new telephone, good service is afforded from the outset. In any case it is not usual for any difficulties incidental to a transfer of this kind to last more than a few days, and as most transfers are timed to be effected at about 2 p.m. on a Saturday, there is ample time for everything to be run into condition by ordinary business hours on the following Monday.

The telephone conditions of a large city, however, provide many additional and interesting problems. In the first place it is impracticable (for economic as well as technical reasons) to convert the whole of a large city to automatic working at one time. It is necessary to carry out the work exchange by exchange. As is frequently the case in engineering matters, very elementary considerations produce serious difficulty. That is so in this instance. It is necessary that a directory be issued to the public so designed as to enable subscribers to call one another with the maximum facility whether the calling or the called party be either an automatic or a manual subscriber. To meet this requirement the most practical device so far proposed, and one that is believed to be completely satisfactory, is to print the directory as follows:—

VICtoria	2796	Barclay, T. W., and Sons, 7, Oxford Court.
NORth	8612	Bell, H., and Co., 19, Kingston-place.
SOUthern	4216	Bentley, T., and Sons, 306, Victoria-avenue.
CENtral	4956	Black, W., and Co., 72, Cannon-row.
MAYfair	9806	Buick, J. C., 316, Albert-road.

It will be noticed that in general the directory entries agree with those at present in force. The distinction, however, lies in the fact that the first three letters of the exchange name are in each case printed in heavy black type. The object of this will be evident from Fig. 4, on the present page, which is a view of the type of dial that will be associated with automatic telephones in large cities. It will be noticed that the number plate in addition, to the ordinary digits, contains 24 of the letters of the alphabet. A call from a subscriber at a manual exchange will be made in the ordinary way to an operator who will complete it as at present. She will be provided with special devices for completing calls to automatic exchanges.

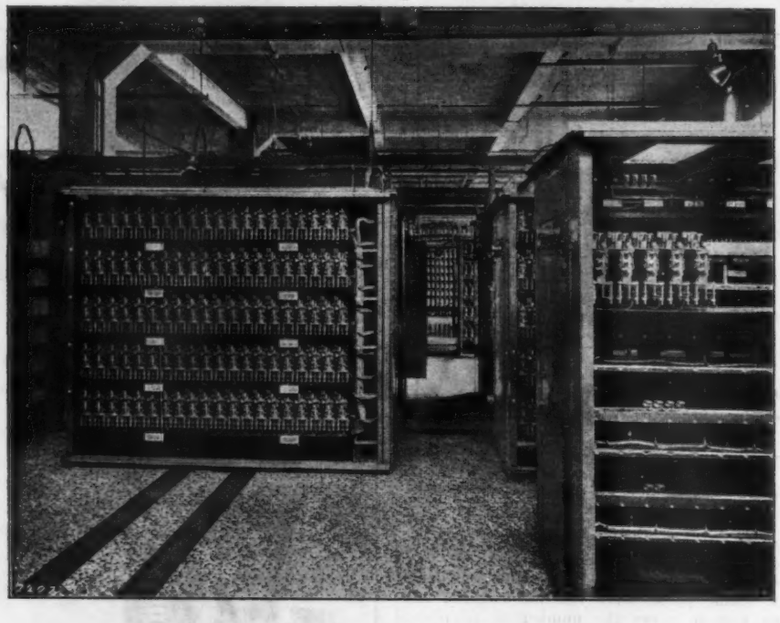


FIG. 3. INSTALLATION OF STEP-BY-STEP SELECTOR.

FIG. 4. SUBSCRIBER'S DIAL.

A call from an automatic subscriber will, however, be effected as follows: If the call be to Central 4956, the subscriber will operate his dial by placing his finger in the finger-hole corresponding to C, rotating the finger plate as far as the finger stop and allowing it to return to normal. This will be repeated for the letter E and the letter N, followed by a similar operation in succession for the digits 4956. If the call be outgoing to an automatic subscriber, the first three trains of impulses will find an idle junction line to the Central Exchange and the following four impulses will find the actual subscriber's line within that exchange. If, however, the call be for a subscriber still on a manual exchange, the first three trains of impulses will, as before, find an idle junction to the required exchange and the remaining four trains of impulses will set up the number in front of a special operator at the manual exchange on a lamp indicator similar in type to that illustrated in Fig. 7, on the opposite page. This "call indicator," as it is termed, consists of an opaque plate below which are small switchboard lamps fronted by transparent outlines of four sets of digits. When the call arrives at the distant exchange a selective device is operated by the impulses so that the lamps "4," "9," "5," "6," as shown in Fig. 7, glow in front of the operator, who then makes connection with the required line if it is disengaged.

For the purposes of automatic working in a large city it has been found desirable to have large groups of junction circuits between the ranks of selector switches, and it is also essential that there shall be a considerable amount of flexibility as regards the positions in which these groups are connected to the contact banks. A group may be connected to a definite position in the banks and then the traffic may increase to such an extent that the group outgrows the number of vacant contacts available for it, and a change in position is essential. When that change is carried out it is necessary that the

same exchange code shall find the same junction group and a translating device is necessary at the originating exchange to convert the code impulses after they arrive, into another code corresponding to the position of the group on the racks.

This is effected by means of a cross-connection device, and the type of system most suited to the operation of large groups and code translation is one in which the operations are performed by a mechanical drive of the selector's moving member, which is quite separate in its operation from the trains of impulses. A system of this kind, therefore, involves a device known as a sender, which accepts the impulses and stores them until another device known as a sequence switch brings the appropriate portions of the switching circuit into operation to receive the impulses that have already been stored.

Fig. 8, subjoined, is a schematic diagram of a system of this kind and operates briefly as follows: The originating subscriber lifts his receiver and the line finder searches until connection is made between its brushes and the calling subscriber's line. A tone is now given to the subscriber, which he is instructed to recognise as the signal that he may "dial." He dials the wanted number, including the code of the required exchange and the impulses are stored on the sender circuit which has been automatically connected to the calling line and to a district selector by means of a sender selector. The district selector operates in accordance with the code of the called exchange and finds the required group of junctions on the district selector bank. The remaining four digits operate the incoming selector and the final selector making connection ultimately with the called subscriber's line.

This system is of the mechanically-driven type. Although it employs sequence switches and senders, it differs somewhat from the stored impulse system illustrated in Figs. 5 and 6. The latter, operated by rotary action and the size of the group of junction circuits that could be used, was limited by the number of contacts in one level, viz., 22. With this system, specially designed for large city traffic, a vertical action is adopted and the selector switches are illustrated in Fig. 9, on page 66. The devices shown on the right-hand side of this figure are sequence switches arranged in this case so that the cam spindle is horizontal and not vertical as in the rotary type. Although the selectors operate by means of vertical action, the sequence switches open and close contacts by the rotation of the spindle under the influence of a magnetic clutch and are similar in principle to those already described.

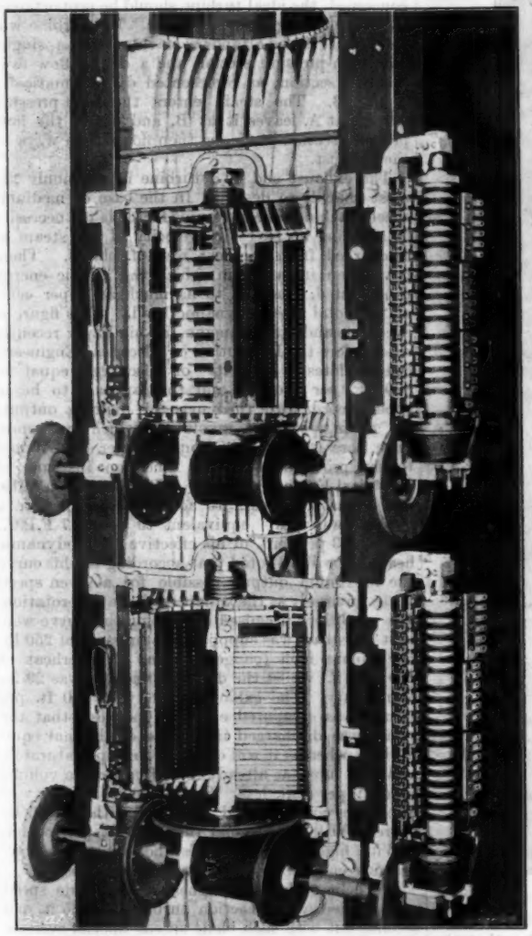


FIG. 5. MOTOR-DRIVEN SELECTORS.

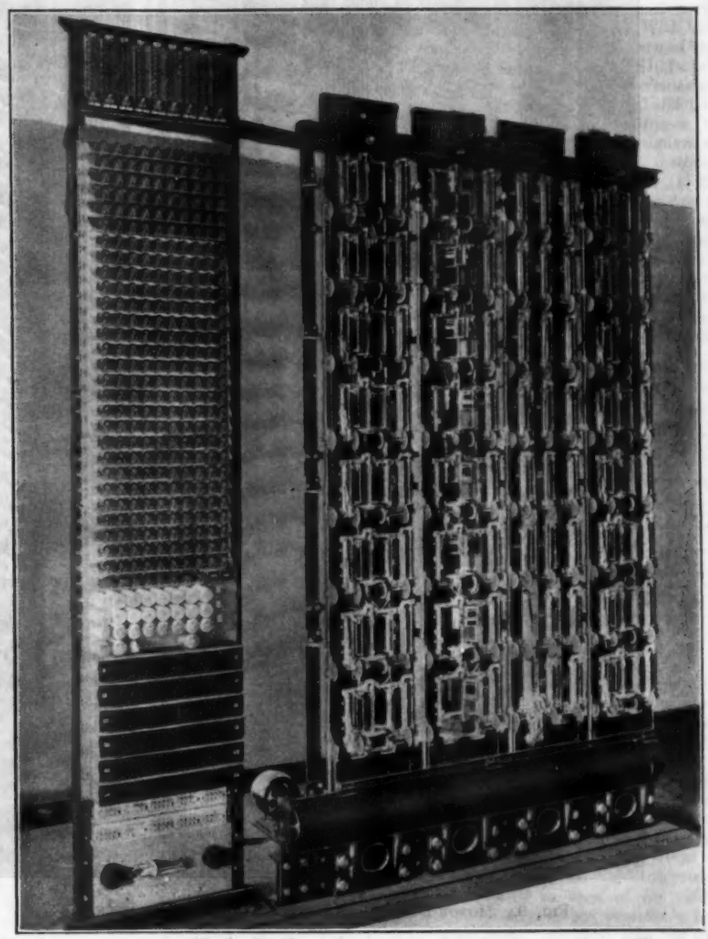
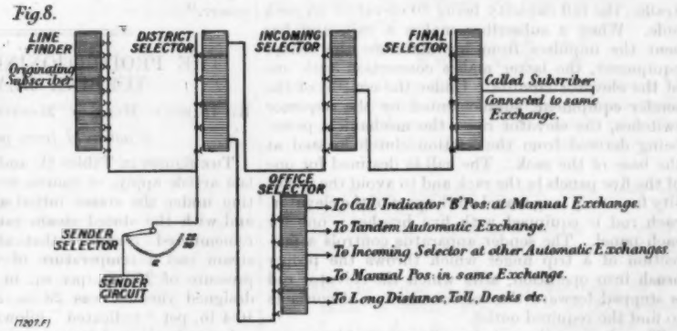


FIG. 6. PANEL OF MOTOR-DRIVEN SELECTORS.

FIG. 7. LAMP INDICATOR.

Fig.8.



This apparatus is designed on panel lines, each panel having capacity for 100 lines ranged vertically. There are five panels per rack so that each rack can accommodate 500 lines. These lines may either be junction circuits to other selectors, or actual subscribers' lines, according to their position as indicated by the schematic diagram given in

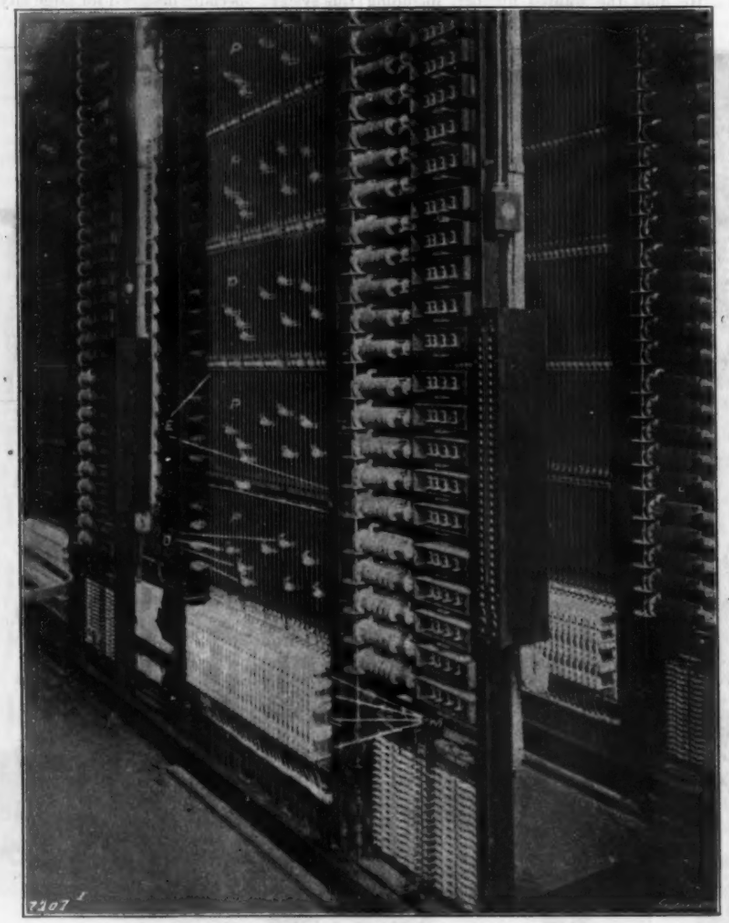


FIG. 9. MOTOR-DRIVEN SELECTORS FOR LARGE INSTALLATIONS.

Fig. 8. The racks are operative from the back as well as the front, and each side is equipped with sufficient elevators, or vertical rods, to carry the traffic, the full capacity being 30 elevators on each side. When a subscriber makes a call, and has sent the impulses from his dial into the sender equipment, the latter makes connection with one of the elevator circuits. Under the control of the sender equipment, supplemented by the sequence switches, the elevator rises, the mechanical power being derived from the friction clutch located at the base of the rack. The call is destined for one of the five panels in the rack and to avoid the necessity for a very long travel on the part of the elevator, each rod is equipped with five brushes; one for each panel. The sender apparatus controls a projection of a trip finger which throws the proper brush into operation, after which the elevator rod is stepped forward the correct number of contacts to find the required outlet.

The release at the end of a call is effected by means of another friction clutch operating in the reverse direction. Before reaching its home position, the tripped brush of the elevator is restored to normal. The friction clutch consists of a magnetically-controlled wheel which at the appropriate time presses a metal strip against a cork covered, continuously-rotating roller. The upper end of this strip is fixed to the lower end of the elevator and the latter is raised or lowered as long as the pressure is maintained.

The degree of mechanical and electrical ingenuity devoted to the design of automatic exchanges is very striking. The systems devised for the service of great cities represent a mass of co-ordinated complexity to which it would be difficult to find a parallel in any other branch of science or industry. In his recent book, "Fifty Years of Electricity," Dr. J. A. Fleming gives it as his opinion that the development of the automatic telephone exchange represents "the high water mark of human creative power."

THE PROPORTIONING OF STEAM TURBINE BLADING.

By HAROLD MEDWAY MARTIN, WH.SC., A.C.G.I.

(*Continued from page* 34).

THE figures in Tables IV and V published in the last article apply, of course, to any turbine operating under the stated initial and final conditions, and with the stated steam rate. These, it will be remembered, premised that at the stop valve the steam had a temperature of 300 deg. C. and a pressure of 250 lb. per sq. in. (gauge) whilst the designed vacuum was 29 in. and the steam rate 10·4 lb. per "indicated" kilowatt-hour.

Let it be desired to proportion a reaction turbine with an output equal to 6,000 i.kw., the conditions being as set out in Table III, page 33 *ante*. At the outset we shall assume an ideal turbine free from tip leakage, and in which every row of blades has the same mean diameter, whilst the blade height is increased in direct proportion to the specific volume of the steam so that the ratio of blade speed to steam speed remains constant for all rows. Moreover, from the perfect symmetry of conditions thus secured it is obvious that if q be the thermodynamic head expended at any row, q will be the same for every row.

Having calculated the blade heights and number of rows required for this ideal turbine we shall, by means of certain "transfer" formulas, transform the ideal turbine into an equivalent turbine of a practicable type. Actually the efficiency of such an ideal turbine would be higher than that of the transformed turbine, but as it is the efficiency of the practicable turbine with which we are actually concerned, the ideal turbine should be proportioned as if its efficiency were the same. The turbine will be assumed to be a tandem machine with a single-flow high-pressure section and a double-flow low-pressure section, as represented diagrammatically in Fig. 3. The steam enters the high-pressure turbine at A, leaves it at B, and enters the low-pressure section at C, and then flows both ways to the exhaust.

The exhaust end of a turbine is commonly the most difficult to design. In the case of medium-speed machines, the governing factor is the necessity of avoiding an excessive velocity of the steam as discharged from the last row of blades. There have been instances in which the kinetic energy thus wasted, amounts to as much as 8 per cent. of the total thermodynamic head. This figure is excessive and Mr. Baumann, in his paper recently read before the Institution of Electrical Engineers, contemplates a velocity of discharge equal to 800 ft. per second, and this appears to be in good accord with the curve of limiting outputs for given speeds of revolution which we reproduce here (see Fig. 4) from a paper contributed to the proceedings of the American Institute of Electrical Engineers by Mr. J. P. Johnson, in 1919. Mr. Johnson appears to accept as permissible a "throwaway loss" equivalent to about 7 F.P.C., or about 3 per cent. of his effective thermodynamic head. It will be noted that according to this curve the maximum output possible for a given speed varies inversely as the square of the rate of rotation. The conditions premised in plotting this curve were that the steam was supplied at a pressure of 250 lb. per square inch (gauge) and at a superheat of 200 deg. F., whilst the designed vacuum was 29 in. of mercury. The exhaust velocity of 800 ft. per second was computed on the hypothesis that the steam was discharged in a state of thermal equilibrium, whereas it will certainly be supersaturated, and thus have, as already stated, a specific volume some 10 per cent. less. Hence the real velocity of discharge contemplated by these authors will be nearer 700 ft. per second than 800 ft. per second.

With high-speed machines the size of the low-pressure end is limited by centrifugal stresses.

We believe that the highest mean blade speed yet adopted with reaction turbines is 785 ft. per second, but with such blade speeds special systems of construction are necessary, in order to provide for the accompanying high centrifugal stresses. To avoid this necessity it is advisable, where practicable, to keep the blade speed down to, say, 575 ft. per second, from which we get for d the limiting mean diameter in inches of the last row of blades the expression:

$$d = 130 \cdot \left(\frac{1000}{\text{R.P.M.}}\right) \quad . \quad . \quad . \quad . \quad (1)$$

From Mr. Johnson's paper, however, it appears that the Westinghouse Company contemplate the adoption of mean peripheral speeds of as much as 600 ft. per second, and for such a speed the constant in the above formula should be increased to about 136. If we assume tentatively that we can, in the case under consideration, work with a blade speed of 575 ft. per second we get from equation (1) above:

$$d = \frac{130}{3} = 43{\cdot}33 \text{ inches}$$

We shall, in accordance with the foregoing, assume that our ideal turbine is to have a mean diameter of 43 in., and for this ideal turbine in which all rows have the same mean diameter, we may write:

$$K = \frac{v}{2} \cdot \left(\frac{d}{10}\right)^2 \left(\frac{\text{R.P.M.}}{100}\right)^2$$

where v denotes the total number of rows of blades including both fixed and moving rows.

But from Fig. 1, on page 2 *ante*, we see that for

an efficiency of 75 per cent. $\frac{K}{U} = 770$, so that:

$$v = \frac{1540\,U}{d^2} \cdot \left(\frac{1000}{R.P.M.}\right)^2$$

which, if $d = 43$ in., reduces to

$$v = 0{\cdot}09254\,U.$$

The best way to calculate v is not to multiply the values of U given in Table V by the above coefficient, but to write

$$v = 0{\cdot}09254\,U = 0{\cdot}09254\left\{\frac{H_s - C}{\eta} - \frac{H - C}{\eta}\right\}$$

We then find

$$\log\frac{0{\cdot}09254\,(H_s - C)}{\eta} \text{ and } \log\frac{0{\cdot}09254\,(H_e - C)}{\eta}$$

and from the former make successive subtractions of one-tenth the difference between the two. As already explained, a check on the accuracy of this work is afforded by the fact that at the tenth subtraction we must get the known value of $\log\frac{0{\cdot}09254\,(H_e - C)}{\eta}$. As before, to provide this check these intermediate values have been taken out to five places, and in this instance the values of the function have also been taken out to five places which is, of course, in excess of practical needs. The value of v is found by subtracting in succession from the value of the entry in the third column opposite L, the entry opposite M, N, O, P and so on. Index numbers are used to check the work as already explained.

TABLE VI.—*Proportions of Ideal Turbine for the Expansion between the Saturation Line and the Condenser Pressure.*

Point.	Log $\frac{0{\cdot}09254\,(H-C)}{\eta}$	$\frac{H-C}{\eta}$	v	Log h^1	Log $h^1 d^2$	h^1	$h^1 d^2$
L	1·52648[3]	33·611[3]	0	$\bar{1}$·5792	2·8461	0·3795	701·6
M	1·50623[3]	32·080[3]	1·531[1]	$\bar{1}$·7375	3·0044	0·5484	1010
N	1·48598[3]	30·618[3]	2·993[3]	$\bar{1}$·8958	3·1627	0·7867	1454
O	1·46573[3]	29·224[1]	4·387[4]	0·0541	3·3210	1·133	2094
P	1·44548[3]	27·892[1]	5·719[4]	0·2124	3·4793	1·631	3015
Q	1·42523[3]	26·622[0]	6·989[3]	0·3707	3·6376	2·348	4341
R	1·40498[3]	25·408[1]	8·203[3]	0·5290	3·7959	3·381	6251
S	1·38473[3]	24·251[3]	9·360[0]	0·6873	3·9542	4·867	8990
T	1·36448[3]	23·146[7]	10·465[7]	0·8456	4·1125	7·008	12960
U	1·34423[3]	22·092[8]	11·519[8]	1·0036	4·2708	10·09	18660
V	1·32398[3]	21·085[7]	12·526[7]	1·1622	4·4291	14·53	26860

Since the same thermodynamic head is expended at each row, we have the relation $q = \frac{U}{v}$. Moreover, in this ideal turbine, it is obvious that v, the velocity of efflux from the blading, is strictly proportional to $\sqrt{q}$, so that we may write $v = l\sqrt{q}$, where l is some coefficient. But $v = \frac{w\,V}{\Omega}$, where w is the weight of steam passed per second, V its specific volume and Ω the area available for flow.

Hence

$$\sqrt{q} = \frac{144\,w\,V}{l \cdot \pi\,h'\,d \sin\alpha}$$

where h' denotes the blade height in inches and α the effective angle of discharge.

But we also have

$$\sqrt{q} = \sqrt{\frac{U}{v}} = \sqrt{\frac{U}{2\,K}} \cdot \frac{d \,.\, R.P.M.}{1000}.$$

Equating these two values of $\sqrt{q}$ and reducing the expressions found, we get for the blade height of our ideal turbine:

$$h^1 = \frac{L}{R.P.M.} \cdot \sqrt{\frac{K}{U}} \cdot \frac{w\,V}{d^2}$$

where L denotes a coefficient which, owing to the fact that the energy maintaining flow through any row of blades consists in part of kinetic energy carried over from the preceding row, varies somewhat with the efficiency, being equal to about 616 when the hydraulic efficiency $\eta = 0{\cdot}7$ and to about 678 when $\eta = 0{\cdot}85$. The above values of L correspond to normal reaction blades, gauged to an opening which is 0·35 pitch. The nominal angle of discharge is thus 20½ deg., but the actual angle, as found by experiment, is about 18½ deg. Between the limits stated L varies nearly linearly with the efficiency, but falls off somewhat rapidly at lower efficiencies. In the present case $\eta = 0{\cdot}75$, and we shall accordingly take L to be 637, so that:

$$h^1 = \frac{637}{R.P.M.} \cdot \sqrt{\frac{K}{U}} \cdot \frac{w\,V}{d^2}.$$

Now from Fig. 1 we note that for $\eta = 0{\cdot}75$ $\frac{K}{U} = 770$, whilst w the weight of steam delivered per second from each end of the double flow low-pressure turbine is 8·667 lb., and $d = 43$ in. Substituting these values we get $\log h^1_s = \bar{1}{\cdot}5792$ and $\log h^1_e = 1{\cdot}1622$. By repeated additions of one-tenth of the difference between these two logarithms we get the values of $\log h^1$ tabulated in column 5 of Table VI. As before, a check is provided by the fact that at the tenth addition we must get the known value of $\log h^1_e$. It will thus be seen that, in order to determine h^1 it was not really necessary to find the values of V tabulated in Table V, only the initial and final values being required.

In a similar way, values of $\log h^1 d^2$ have been tabulated in column 9 of Table VI.

In Fig. 5, the values of h^1 for points T, U and V have been plotted, and we shall assume that there are stages at $v = 12{\cdot}53$ and $11{\cdot}53$. The corresponding blade heights can then be read from the curve. Next to practicalise the turbine we shall replace these two blades by two blades both of the same height, this height being such that with the same pressure before and after the group, as in the ideal turbine, the weight of steam passed is the same. It will be shown later on that the required blade height is very nearly the same as the height on the curve corresponding to $v = \frac{12{\cdot}53 + 11{\cdot}53}{2} = 12{\cdot}03$. The corresponding value of h^1 as read from the curve is 12·10 in. This is the height required for a normal blade, and would be rather long for a mean diameter of 43 in. By substituting semi-wing blades, providing 1½ times as much area for flow, the height would be reduced to 8·06 in. With such blades, however, the residual velocity of the steam as finally discharged would be higher than is desirable. We shall therefore assume that special blades are used equal in height to about one-fifth the mean diameter of the stage, or, say, 8⅛ in., and assume them to be gauged to such an opening that the area provided for flow is the same as with normal blades 12 in. long, gauged to an opening of 0·35 pitch. Experiment shows that with this gauging the actual angle of discharge is about 18½ deg. The sine of this angle is 0·3145, so that the 8⅛-in. blades should have an actual angle of discharge defined by the relation $\sin\alpha = \frac{72 \times 0{\cdot}3173}{8{\cdot}625} = 0{\cdot}442$.

Hence $\alpha = 26$ deg. nearly. The nominal angle would probably be 1 deg. or 2 deg. more. With this value the apparent residual absolute velocity of the steam* as finally discharged will be about 810 ft. per second, and the kinetic energy lost to the condenser will amount to about 3 per cent. of the total effective thermodynamic head. "Throwaway" losses of this magnitude are accepted by most designers of high speed turbines, and in the present instance could only be reduced in one of three ways: (1) By adopting a larger mean diameter at the last row of blading, and providing for the consequent increase of centrifugal stresses; (2) by making the blade longer than one-fifth the diameter of the last row, a policy which is now finding favour; (3) by gauging the 8⅛-in. blades to a wider opening. Such an operation would modify the pressure distribution in much the same way as a decrease in the designed vacuum, and as in that case the effects would not be appreciable save at the final stages.

In the present case we shall accept the 3 per cent. loss and take the last group as two rows of blades (one fixed) 8⅛ in. high and having a mean diameter of 43 in. The drum diameter here will therefore be 34⅛ in.

We shall later on calculate the theoretical value of h, and compare this with the height measured from the diagram in the way above explained. When the ratio of expansion per group is moderate, the diagram height differs very little from the theoretical, and in other cases the difference is hardly worth considering in view of the circumstance that the blade heights are commonly made even eighths of an inch. We shall take the drum diameter for the groups adjacent to the last group as 35 in., and to a drum of this diameter we have to transfer the blades of the ideal turbine.

The equation

$$h^1 = \frac{L}{R.P.M.} \cdot \sqrt{\frac{K}{U}} \cdot \frac{w\,V}{d^2}$$

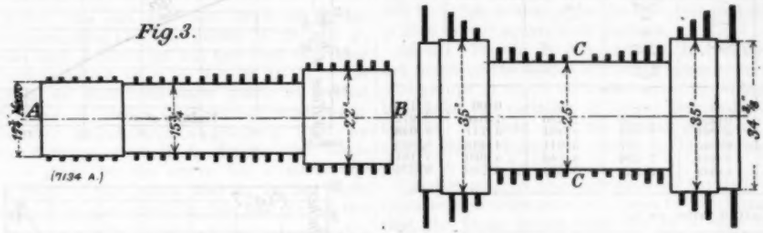
shows that if we alter the mean diameter d the value of $h\,d^2$ must remain constant. Hence, calling D the drum diameter and h the height of a blade transferred to this diameter, we must have:

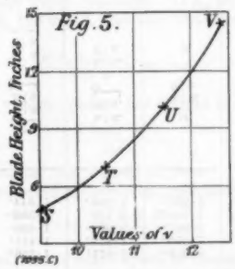
$$h\,(h + D)^2 = h^1\,d^2.$$

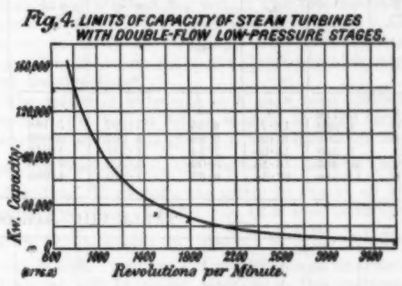
Values of the quantity on the right have been tabulated in Table VI.

Knowing D the value of h can be very rapidly determined by means of the ordinary 10-in. slide rule.

Thus the value of $h^1 d^2$ corresponding to P in the table is 3015, whilst $D = 35{\cdot}25$. Assume $h = 2$, then $h + D = 37{\cdot}25$. Setting the cursor over 3015 on the lowest scale, one end of the slide is brought against 37·25 on the lower scale and the square of this quantity read on the top scale as 1,388. Then dividing 3,015 by this number gives us 2·175 as an approximate value of h. Repeating the operation with this value we get finally the value tabulated in the last column of







* It will be shown later that the true theoretical height for the group is rather less than 12 in., so that the real loss by "throwaway" is less than the value here given.

Table VII. The whole operation commonly takes less than 1 minute. It is convenient, with the value of h thus found still on the slide, to determine the value of $\frac{h}{h^1}$ which is tabulated in the seventh column of Table VII, under the heading $\left(\frac{h}{h^1}\right)_n$. This is required in determining the number of rows n on the practicable turbine corresponding to ν on the ideal turbine. The relation between n and ν is fixed by the consideration that to maintain the efficiency unchanged the value of K must increase by the same amount between corresponding points on the ideal and on the practicable turbine.

From this it follows that:

$$\frac{n}{\nu} = \frac{d^2}{(h + D)^2}$$

This relation holds whatever the increment of K, and if we take this increment as an infinitesimal we get:

$$\frac{d\,n}{d\,\nu} = \frac{(h + D)^2}{d^2}$$

but

$$h\,(h + D)^2 = h^1\,d^2.$$

Hence

$$\frac{d\,n}{d\,\nu} = \frac{h}{h^1}$$

There are two methods available for determining n from the known values of $\frac{d\,n}{d\,\nu}$. Of these alternatives the one is simpler in theory and the other in practice. Taking the former first, we have

$$n = \int \frac{h}{h^1}\,.\,d\,\nu\,. = \frac{\nu_N - \nu_0}{6}\left[\left(\frac{h}{h^1}\right)_0 + \left(\frac{4\,h}{h^1}\right)_{\frac{1}{2}} + \left(\frac{h}{h^1}\right)_N\right]^*$$

Plotting the values of $\frac{h}{h^1}$ against ν, as in Fig. 6, we can then find simply and easily the values of n corresponding to the known values of ν. The method is shown in Table VII, which is self-explanatory. The values of $\left(\frac{h}{h^1}\right)_{\frac{1}{2}}$ are, of course, read from the curve.

The values of n and h have been taken out with more accuracy than is really necessary, with the ultimate object of determining with some precision the actual magnitude of such errors as may be inherent in the method.

The alternative method of determining n does not necessitate the plotting of a curve but requires some slight knowledge of the calculus of finite differences, but the arithmetical work required is less than is needed by the plan already described. The method will be readily understood on reference to Table VIII. Here the entries under the heading $\Delta\,\nu$ are the first differences of ν and are found by subtracting each entry in the column headed ν from that below it. A check on the accuracy of the work is provided by the "index numbers" printed over each entry, the use of which was explained on page 34, *ante*. In a similar way the second differences printed under the heading $\Delta^2\,\nu$ are derived from the entries in the preceding column. If m denote the order of the points P, Q, R, etc., we get the entries under the heading m. Then by a known theorem in the calculus of finite differences we have:—

$$\frac{d\,\nu}{d\,m} = \Delta\,\nu - \frac{\Delta^2\,\nu}{2} + \frac{\Delta^3\,\nu}{3} - \&c.$$

Neglecting $\Delta^3\,\nu$ as small we get the values of $\frac{d\,\nu}{d\,m}$ entered in the adjoining column, by subtracting from $\Delta\,\nu$ half the corresponding value of $\Delta^2\,\nu$.

TABLE VII.—CALCULATION OF n.

Point.	ν.	$\nu_P + \nu$	$\frac{1}{3}(\nu_P + \nu) =$	$\left(\frac{h}{h^1}\right)_{\frac{N}{12}}$	$4\left(\frac{h}{h^1}\right)_{\frac{N}{12}}$	$\left(\frac{h}{h^1}\right)_N$	$\left(\frac{h}{h^1}\right)_N + 4\left(\frac{h}{h^1}\right)_{\frac{N}{12}}$	$\left(\frac{h}{h^1}\right)_0 + 4\left(\frac{h}{h^1}\right)_{\frac{N}{12}}$	$\nu_N - \nu_0$	n	h
P	5·719	—	—	—	—	1·322	—	—	—	0·00	2·156
Q	6·989	12·71	6·35	1·297	5·188	1·266	6·454	7·776	1·270	1·646	2·972
R	8·203	13·92	6·96	1·267	5·068	1·197	6·265	7·587	2·484	3·141	4·048
S	9·360	15·08	7·54	1·237	4·948	1·117	6·065	7·387	3·641	4·483	5·435
T	10·465	16·18	8·09	1·202	4·808	1·026	5·834	7·156	4·746	5·660	7·181
U	11·519	17·24	8·62	1·170	4·680	0·929	5·649	6·931	5·800	6·700	9·374

TABLE VIII.—ALTERNATIVE CALCULATION OF n.

Point.	ν	$\Delta\,\nu$	$\Delta^2\,\nu$	m	$\frac{d\,\nu}{d\,m}$	$\frac{d\,n}{d\,\nu}$	$\frac{d\,n}{d\,m}$	$\frac{1}{2}\frac{d\,n}{d\,m} + \frac{d\,n}{d\,m}$	$\frac{d\,n}{d\,m}]_0 + \frac{d\,n}{d\,m}$	$\frac{1}{2}\left\{\left(\frac{d\,n}{d\,m}\right)_0 + \frac{d\,n}{d\,m}\right\}$	$n = S - \frac{1}{2}\left\{\left(\frac{d\,n}{d\,m}\right)_0 + \frac{d\,n}{d\,m}\right\}$
P	5·719[4]	—	—	0	1·298	1·322	1·716[6]	—	—	—	0·00
Q	6·989[5]	1·270[1]	—	1	1·242	1·266	1·572[6]	3·288[3]	3·288[3]	1·644[6]	1·644[6]
R	8·203[8]	1·214[8]	−056[2]	2	1·183	1·197	1·416[3]	4·704[6]	3·132[0]	1·566[0]	3·138[6]
S	9·360[0]	1·157[9]	−057[3]	3	1·131	1·117	1·263[2]	5·967[0]	2·979[6]	1·490[3]	4·477[4]
T	10·465[7]	1·105[7]	−052[7]	4	1·078	1·026	1·106[8]	7·073[8]	2·822[5]	1·411[7]	5·662[1]
U	11·519[5]	1·054[1]	−051[6]	5	1·028	0·929	0·955[1]	8·028[0]	2·671[7]	1·336[4]	6·694[5]

Bearing in mind that $\Delta^2\,\nu$ is negative we have got to add to 1·270 the half of 0·056 in order to find $\frac{d\,\nu}{d\,m}$ for $m = o$. Similarly for $m = 1$ we add to 1·214 the half of 0·057. We can proceed in this manner down to $m = 3$, following in each case a diagonal line through ν, $\Delta\,\nu$ and $\Delta^2\,\nu$. When we get to the point $m = 4$, however, the diagonal line meets with no entry for $\Delta^2\,\nu$ and we must accordingly turn and work from the bottom of the table upwards. Now in reversing the order of a set of figures we do not change the numerical value of the differences but the signs of all differences of an odd order are reversed, whilst those of an even order remain unchanged. Hence if we write $M = -m$ we have for the point U

$$\frac{d\,\nu}{d\,M} = -1·054 - \tfrac{1}{2}(-0·051) = -1·028 = -\frac{d\,\nu}{d\,m}\Big]_5$$

and for the point T we get

$$\frac{d\,\nu}{d\,M} = -1·105 - \tfrac{1}{2}(-0·052) = -1·078 = -\frac{d\,\nu}{d\,m}\Big]_4$$

Now

$$\int \frac{d\,n}{d\,\nu}\,.\,d\,\nu = \int \frac{d\,n}{d\,\nu}\,.\,\frac{d\,\nu}{d\,m}\,d\,m\,. = \int \frac{d\,n}{d\,m}\,d\,m.$$

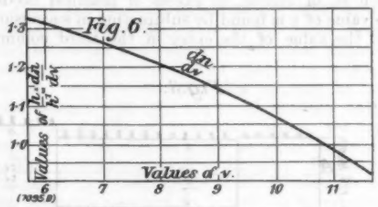
Hence, entering from Table VII the known value of $\frac{d\,\nu}{d\,n} = \frac{h}{h^1}$. We are able to calculate the values of $\frac{d\,n}{d\,m}$ shown in column 8 of Table VIII, and as the successive values of m are equidistant we can find n by the trapezoidal rule, which may be written in the form

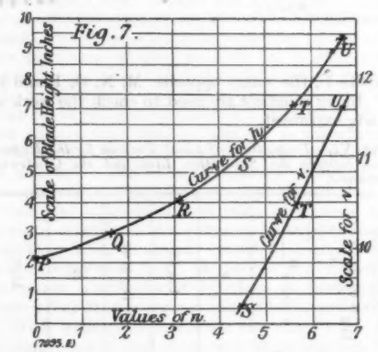
$$\int_0^m y\,d\,m = y_0 + y_1 + y_2 + \&c.,+ y_m - \tfrac{1}{2}(y_0 + y_m).$$

Values showing the sum of $\frac{d\,n}{d\,m}$ up to the different values of m are entered in column 9, whilst in the next column the value entered is that of $\frac{d\,n}{d\,m}\Big]_0 + \frac{d\,n}{d\,m}$ and the half of this is entered in the next column. Subtracting these half values from S, we get the values of n given in the last column. Comparing these with values determined by rule previously given it will be seen that the discrepancy does not exceed 1 part in 400 which proves that the simple trapezoidal rule used is more than sufficiently exact for practical requirements.

Plotting down values of h against n we get the curve of blade heights reproduced in Fig. 7.

Now the group of semi-wing blades ended with a blade at $\nu = 11·53$. Hence the value of n with which we are now to start will be that corresponding to $\nu = 10·53$. and if we plot n against ν for the points S, T and U we see that this value is $n = 5·55$. We have then to replace blades at $n = 5·55$ and 4·55 by two blades both of the same height $\overline{h}$, which, with the same pressure drop will pass the same amount of steam. As before, we take this height to be that corresponding on the curve to $n = \frac{5·55 + 4·55}{2} = 5·05$, whence $\overline{h} = 6·20$. Similarly two blades at $n = 3·55$ and $2·55$ are replaced by blades having a height equal to the ordinate of the curve at $n = \frac{3·55 + 2·55}{2} = 3·05$, whence $\overline{h} = 3·97$. Proceeding in this way we get for this portion of the low-pressure turbine with a 35¼ in. drum the following values:—[*]





Group.	IV.	V.	VI.	VII.
Blade height $\overline{h}$	2·62	3·97	6·20	8¼*
Total No. of rows in group, inclusive of fixed rows	2	2	2	2

The values given above require correction for tip clearance, and have to be rounded off to even eighths of an inch, but for the present these corrections will be postponed. For plotting the curves the R.H.S. curves published by Messrs. Cassell and Co. will be found very useful. One of the set can generally be found to line up with four points.

For the rest of the low-pressure turbine a smaller drum diameter is necessary since the blade heights would otherwise be so small as to involve excessive tip clearance losses.

The section of the turbine already completed ends with $n = 5·55 - 6 = -0·45$, and by plotting

* This is one of Cote's formulas for approximate integration, and is exact for any curve which can be adequately represented by four ordinates.

* Special blades on a drum 34¾ in. in diameter.

down ν against n we find that the value of ν with which the new section of the turbine must commence is 5·4, which, as will be seen from Tables VII or VIII, lies between points O and P. Let us assume that the diameter of the drum for this second section of the turbine is to be 25 in. Then, as before, we compute h from the formula:

$$h\,(h + 25)^2 = h^1\,d^2$$

from which, by a few minutes' work with the slide rule we get the values of h given in Table IX and also the values of $\frac{h}{h^1}$ given in the adjoining column.

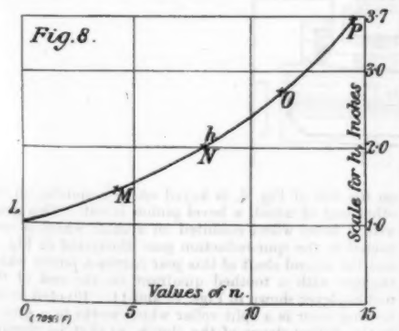
From the known values of $\frac{h}{h^1}$ we can determine n exactly in the same way as before. These values of n are given in the last column, and in Fig. 8 we have plotted h against these values of n.

TABLE IX.—*Blade Heights for 25" Drum.*

Point.	n	$h^1\,d^2$	h	$\frac{h}{h^1}$	n
L	0	701·6	1·035	2·728	0·00
M	1·531	101·0	1·443	2·642	4·11
N	2·993	145·4	1·994	2·535	7·89
O	4·387	209·4	2·725	2·405	11·34
P	5·719	301·5	3·668	2·248	14·44

As before, we can also plot down the values of ν corresponding to the points N, O and P, and from such a curve we will find that the value of n corresponding to $\nu = 5{\cdot}4$ is 13·75. For this drum we shall take each group to consist of four rows of blades (inclusive of fixed rows). The number included in a group is fixed by the consideration that if h_0 denote the blade height as given by the curve for a blade one unit in front of the group, and h_N be the blade height given by the curve for the last row of the group, the ratio of $\frac{h_N}{h_0}$ should so far as is practicable lie between 1·3 and 1·4. At the low-pressure end of large high-speed turbines this is not generally practicable, as even with only two rows in the group (one of them fixed) the ratio may exceed 1½. The *rationale* of the above rule is that the values of h as plotted are nearly proportional to the volume of the steam after its discharge from that particular blade row, and to avoid excessive fluctuations in the ratio of blade speed to steam speed when the group of variable blade height is replaced by one in which all blades have all the same height, the ratio of volume expansion should if practicable be kept down to 1·4 as a maximum and is preferably rather less.

In Fig. 8 we start with a row at $n = 13{\cdot}75$. Then there will also be rows at $n = 12{\cdot}75$, $11{\cdot}75$ and $10{\cdot}75$ and the height $\overline{h}$ of a group of four blades to replace these and pass the same



weight of steam for the same pressure drop will, as before, be very approximately the height on the curve corresponding to $n = \frac{13{\cdot}75 + 10{\cdot}75}{2} = 12{\cdot}25$. This height is 2·98 in. For the next group of four blades the mean height $\overline{h}$ will be that corresponding to $n = 12{\cdot}25 - 4 = 8{\cdot}25$, and from the curve we find that this is 2·07 in. For the third group we must take $\overline{h}$ as the height of the curve at $n = 8{\cdot}25 - 4 = 4{\cdot}25$, so that $\overline{h} = 1{\cdot}44$ in.

TABLE X.

Point.	ν	Log h^1	Log $h^1\,d^2$	h^1	$h^1\,d^2$	15¾-in. Drum. h	$\frac{h}{h^1}$	n	22-in. Drum. h	$\frac{h}{h^1}$	n
A	0·00	$\bar{1}$·93220	2·40580	0·8555	—	—	—	—	—	—	—
B	7·24	0·00633	2·47993	1·015	—	—	—	—	—	—	—
C	14·23	0·08046	2·55406	1·204	—	—	—	—	—	—	—
D	20·96	0·15459	2·62819	1·428	424·8	1·437	1·002	0·00	—	—	—
E	27·46	0·22872	2·70232	1·693	503·8	1·662	0·9817	6·44	—	—	—
F	33·72	0·30285	2·77645	2·009	597·8	1·915	0·9534	12·50	1·119	0·5567	0·00
G	39·76	0·37698	2·85058	2·382	708·9	2·200	0·9232	18·17	1·305	0·5480	3·39
H	45·59	0·45111	2·92471	2·826	840·9	—	—	—	1·520	0·5379	6·50
I	51·20	0·52524	2·99884	3·351	997·3	—	—	—	1·765	0·5266	9·48
J	56·61	0·59937	3·07297	3·976	1183	—	—	—	2·046	0·5142	12·30
K	61·82	0·67350	3·14710	4·715	1403	—	—	—	2·368	0·5010	14·95

The total number of blades thus accounted for is 12, and hence a fifth group would commence with a blade at $13{\cdot}75 - 12 = 1{\cdot}75$, but it will be better not to have a fifth group, but to transfer the blades to the high-pressure turbine, as if retained on the 25-in. drum the height would be somewhat small in comparison with the mean diameter. By plotting ν against n for the points L, M, N, we see that $n = 1{\cdot}75$ corresponds to $\nu = {\cdot}646$, and if we plot log p against ν we shall find that the logarithm of the pressure at this point, that is to say, the pressure at entrance to the low-pressure turbine, will be 1·398, so that p_1 for the low-pressure turbine is 25·0 lb. per square inch absolute.

Messrs. Brown, Boveri and Co. frequently do not break up the blades of the low-pressure turbine into groups in which all blades are of equal height, but make the variation in height practically continuous. In that case the actual profile of the casing should follow as closely as practicable the curves in Figs. 7 and 8.

Coming now to the high-pressure turbine, it is necessary (in order to reduce losses by tip clearance) that the blade height shall not be a very small fraction of the mean diameter. If h_0 be the blade height and d_0 the mean diameter, the area available for flow is

$$\frac{\pi\,h_0\,d_0 \sin\alpha}{144} \text{ sq. ft.}$$

So that the volume passed per second is

$$\frac{v\,\pi\,h_0\,d_0 \sin\alpha}{144}$$

where v denotes the speed of flow. The blade speed s is moreover given by the relation:

$$s = \frac{d_0 \,.\, \text{R.P.M.}}{229{\cdot}2}$$

So that if the ratio of blade speed to steam speed be δ we can replace v in the above expression by

$$\frac{\text{R.P.M.}}{229{\cdot}2} \cdot \frac{d_0}{\delta}$$

Hence the volume passed per second

$$= \frac{\text{R.P.M.}}{229{\cdot}2} \cdot \frac{d_0}{\delta} \cdot \frac{\pi\,h_0 d_0 \sin\alpha}{144} = V_0 w$$

Taking h^1_0 as $0{\cdot}05\ d_0$, we thus get:

$$d_0 = 87 \,.\, \left(\frac{w\,V_0\,\delta}{\text{R.P.M.}}\right)^{\frac{1}{3}}.$$

The approximate value of δ has been plotted against $\frac{K}{U}$ in Fig. 1, page 2 *ante*. In the present case $\frac{K}{U} = 770$, so that $\delta = 0{\cdot}532$, whilst as this high-pressure turbine is of the single-flow type the value of w will be 17·33 lb. per second, whilst $V_0 = 2{\cdot}493$ cub. ft. per pound. Substituting these values we get $d_0 = 17{\cdot}15$ in., say 17¼ in., as the mean diameter of the first group of blades.

As before, we shall assume an ideal turbine of this mean diameter, and calculating the blade heights for this will then transform it into a practical type.

Since the value of $\frac{K}{U}$ is the same for the high-pressure turbine as for the low-pressure section, we have, as before, the two equations:

$$\nu = \frac{1540}{d^2}\left(\frac{1000}{\text{R.P.M.}}\right)^2$$

and

$$h^1 = \frac{637}{\text{R.P.M.}} \cdot \sqrt{\frac{K}{U}} \cdot \frac{w\,V}{d^2}.$$

Taking d as 17¼ in., and substituting in the foregoing, we get:

$$\nu = 0{\cdot}5751\ U.$$

whilst

$$\log h^1]_A = \bar{1}{\cdot}9322$$

and

$$\log h^1]_K = 0{\cdot}6735.$$

We also have

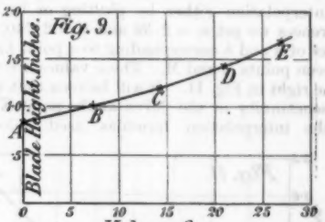
$$\log h^1 d^2]_A = 2{\cdot}4058$$

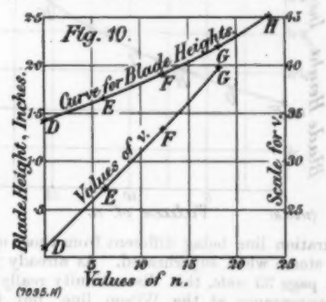
and

$$\log h^1 d^2]_K = 3{\cdot}1471.$$

We thus get the values tabulated below, where the intermediate values of log h^1 are determined by successive additions of one-tenth the difference between log $h^1]_A$ and log $h^1]_K$. The intermediate values of log $h^1\,d^2$ are similarly determined. As before, to facilitate checking, these intermediate logarithms are taken out to five places, of which only four are significant.

The values of h^1 from A to E have been plotted down in Fig. 9. As before, in order to avoid large variations within the group of the ratio of steam speed to blade speed, the fraction $\frac{h_N}{h_0}$ will be kept below 1·4. If we take the group to consist of 12 blades, the value of h^1 for $\nu = 12$ is seen from the figure to be 1·142, so that $\frac{h_N}{h_0} = \frac{1{\cdot}142}{85{\cdot}55} = 1{\cdot}33$. which is within the limit given. Then with an error: which (as will be shown later) is in this instance





less than 1 per cent., the weight of steam passed, with the same pressure difference, will be the same if the 12 blades having the heights indicated by the curve are replaced by 12 blades of height $\overline{h}$, where $\overline{h}$ is the height on the curve corresponding to $\nu = \frac{1 + 12}{2} = 6{\cdot}5$. This height is 0·996 in.

We shall assume that the next group is of the same mean diameter, and also consists of 12 blades, which have a height $\overline{h}$ equal to that of the curve for $\nu = \frac{13 + 24}{2} = 18{\cdot}5$. This height is 1·346. The corresponding drum diameter is accordingly $17{\cdot}25 - 1{\cdot}35 = 15{\cdot}90$, say 15¾ in., and the third group of blades will be given the same drum diameter.

As before, we determine h by the equation:

$$h\,(h + D)^2 = h^1\,d^2$$

and n from the equation

$$\frac{d\,n}{d\,\nu} = \frac{h}{h^1}$$

Values of $\frac{h}{h^1}$ are given in the table, and we deduce the corresponding values of n as already explained, page 68 *ante*. Next, plotting h against n we get the curve in Fig. 10. In this diagram ν has also been plotted against n. Group No. 2 ended with $\nu = 24$, which from the curve corresponds, it will be seen, to $n = 3$. The first blade of group III will therefore correspond to $n = 4$, and if we take the group to consist of 14 rows, the height $\bar{h}$ of these rows, if all are made of the same height, will be the value of h opposite to $n = \frac{4 + 17}{2} = 10{\cdot}5$, so that $\bar{h} = 1{\cdot}836$.

From the curves it will be seen that Group III terminates with $\nu = 38{\cdot}52$.

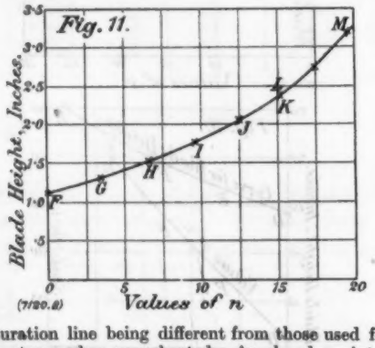
The drum diameter will now be increased to 22 in., and in just the same way as before we get the values of h, $\frac{h}{h^1}$, and n given in Table X.

It will be remembered that the practical L.P. turbine ended at a point corresponding to 0·646 rows of blades on the ideal L.P. turbine.

This ideal low-pressure turbine had a mean diameter of 43 in., and if we transfer the blades from this ideal turbine to a drum 22 in. in diameter we get the values of h, $\frac{h}{h^1}$ and n shown below. In making this transfer, it must be borne in mind that since the ideal low-pressure turbine is of the double flow type, whilst the high-pressure turbine is single flow, the values of h^1 and $h^1 d^2$ given in Table VI, on page 67, must be doubled before beginning the calculation.

Point.	ν	h^1	$h^1 d^2$	h	$\frac{h}{h^1}$	n
L	0·00	0·7590	1403·2	2·363	3·116	0·00
M	1·531	1·0928	2020·0	3·186	2·914	4·64
N	2·993	1·5734	2908·0	4·225	2·682	8·73

By interpolation either by plotting or by second differences we get $n = 2{\cdot}39$ and $h = 2{\cdot}740$, as the values of n and h corresponding to a point half-way between points L and M. These values are plotted to the right in Fig. 11. It will be seen that there is a discontinuity in the curve at the point K L due to the interpolation formulas used below the



saturation line being different from those used for the steam when superheated. As already pointed out, page 33 *ante*, this discontinuity really makes its appearance at the Wilson line, but for the reasons there given it was considered legitimate and simpler to assume it to occur at the saturation line.

If we take six rows (inclusive of fixed blades) as forming a group in this section of the turbine, we can, as before, scale off the values of $\bar{h}$, and we thus get for the complete make-up of the whole turbine the figures given in Table XI.

These diagram values of $\bar{h}$ require correction for tip clearance; and for the fact that only part of the total steam passes through the blading, the remainder making its way through the dummies. A more important correction still is that involved in the practical convenience of making the blade heights even eighths of an inch, which in the case of short blades may involve a correction of over 5 per cent. The very considerable magnitude of this correction makes it fully legitimate to measure off the blade heights from the curves by the empirical rule given. As already explained in replacing a group

TABLE XI.—*High Pressure Turbine.*

Group No.	Blade Height $\bar{h}$ (from Diagram).	No. of Rows in Group (including Fixed Blades).	Mean Diameter d.	Drum Diameter D.
I	0·995	12	17½	—
II	1·346	12	—	15⅝
III	1·836	14	—	15⅝
IV	1·500	6	—	22
V	2·130	8	—	22

of blades of varying height by a similar number of blades all of the same height, this height $\bar{h}$ should be chosen so that the total weight of steam passed with the given pressure difference shall be unaltered.

(To be continued.)

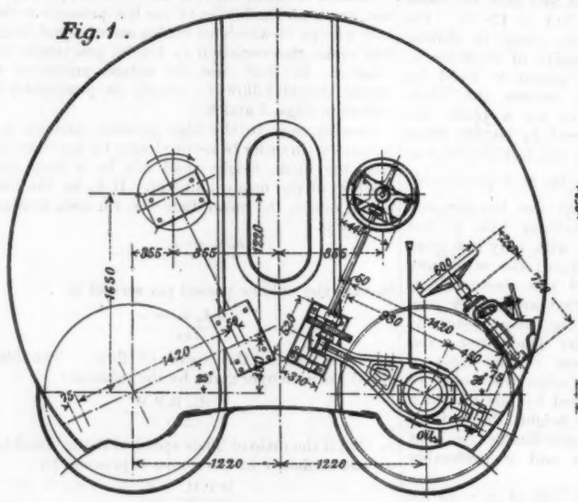
THE POMINI FRICTION CLUTCH.

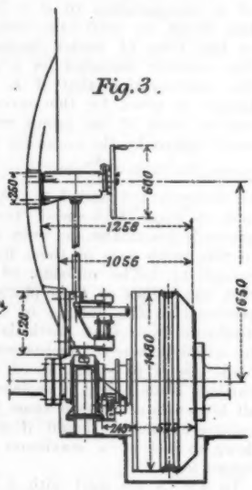
THE fact that trouble is still experienced in the use of friction clutches, even for the transmission of moderate powers at comparatively low speeds, seems to indicate that the design of these appliances is not always all that could be desired. Probably, however, such troubles as now occur arise mainly from the fact that clutches are not infrequently called upon to work under conditions never contemplated by their designers. Actually such appliances are available for all ordinary requirements, and if these are made clear to any reliable maker, a clutch capable of giving long and satisfactory service can be supplied. When, however, the horse-power to be transmitted or the revolutions per minute, or both these parameters, run into thousands, the problem of producing a suitable clutch is one of considerable difficulty. Such a clutch must be capable of engaging and disengaging easily and quickly, of transmitting the full torque without slipping, and must be able to resist wear so as to give a reasonably long life. Moreover, it is usually necessary in practice to make some provision in the design for a certain amount of relative movement, both axially and radially, between the driving and driven shafts.

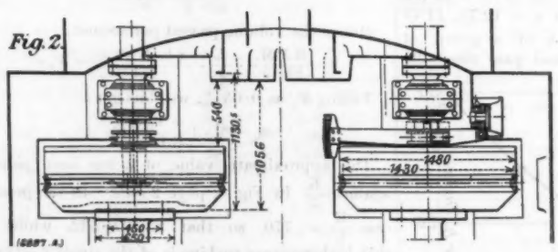
Clutches which appear to supply these *desiderata* have been designed and patented by Mr. Ottorino Pomini, and a considerable number made by the Società Anonima Luigi Pomini, of Castellanza, Italy, during and since the war, are now giving satisfactory service. Before describing an example of these clutches we may mention that several designed to transmit 3,000 h.p. at 300 r.p.m. were delivered to the Italian Navy for war service, and one of these clutches was used in a rolling mill to transmit 6,000 h.p. at 300 r.p.m. for three years without giving any trouble, although the main parts of this particular clutch were constructed entirely of cast iron. Other clutches have been designed for the transmission of 1,200 h.p. at from 1,500 r.p.m. to 2,000 r.p.m., and a large number of these have been supplied to work with Isotta Fraschini motors developing 800 h.p. at 1,400 r.p.m. Altogether, Pomini clutches capable of transmitting an aggregate of 200,000 h.p. have been applied to submersible and other fast boats, and the design for a single clutch to transmit 10,000 h.p. at 3,000 r.p.m., we understand, is now under consideration by the Italian naval authorities.

The clutch, which we illustrate on this page, and on Plate III which accompanies this issue, is known as the "Superpotente," and is intended to transmit 3,000 h.p. at 330 r.p.m. It is suitable for coupling the Diesel engines to the propeller shafts in submersible boats, and Figs. 1, 2 and 3 illustrate the general arrangement of two clutches and their operating mechanism in a twin-screw vessel of this type. Fig. 1 is a transverse section of the boat, looking towards the stern and showing the bulkhead on which the operating gear is mounted, while Figs. 2 and 3 are longitudinal sections in the horizontal and vertical planes, respectively. The propeller is, of course, to the left of Fig. 3, while the engine is to the right. The barring gear, the worm wheel of which is cut on the clutch body, should be noted.

From the drawings of the operating mechanism reproduced in Figs. 4 to 17 on Plate III, its design and construction can be followed with but little explanation. The hand wheel, part of which is shown





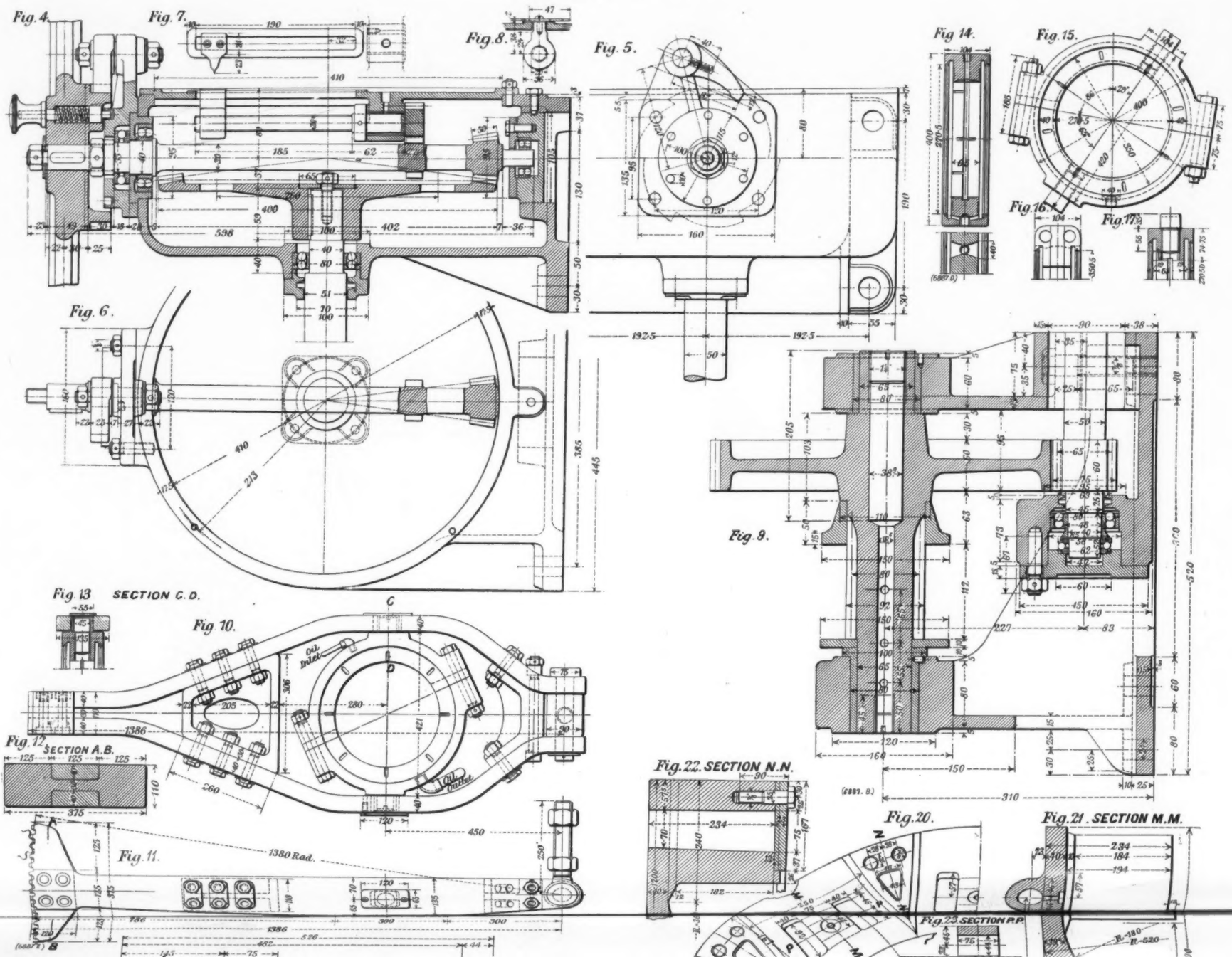


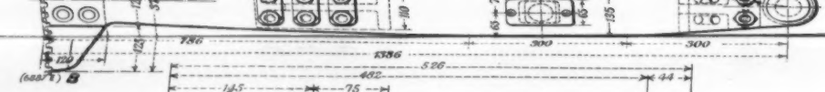
on the left of Fig. 4, is keyed on to a spindle on the other end of which a bevel pinion is cut. This gears with a bevel wheel mounted on a shaft which is connected to the spur-reduction gear illustrated in Fig. 9, and the second shaft of this gear carries a pinion which engages with a toothed quadrant on the end of the rocking lever shown in Figs. 10 and 11. Pivoted to the rocking lever is a split collar which works in a groove in the sliding sleeve of the clutch, so that by turning the handwheel, the sleeve is moved along the shaft to engage or disengage the clutch, as will be explained subsequently. The handwheel, it will be noticed from Figs. 4, 5 and 6, is fitted with a ratchet wheel, with which a pawl engages to prevent the wheel from running back under the influence of some springs in the clutch, which will be referred to later. A spring plunger, clearly shown in Fig. 4, is also provided to lock the wheel in any position. The indicator, shown in Figs. 4, 7 and 8, serves to show the operator when the clutch is fully engaged or disengaged. It comprises a pointer which is moved over a scale by means of a

THE "SUPERPOTENTE" FRICTION CLUTCH.

CONSTRUCTED BY THE SOCIETÀ ANONIMA LUIGI POMINI. ENGINEERS, CASTELLANZA, ITALY.

(For Description, see Page 70.)





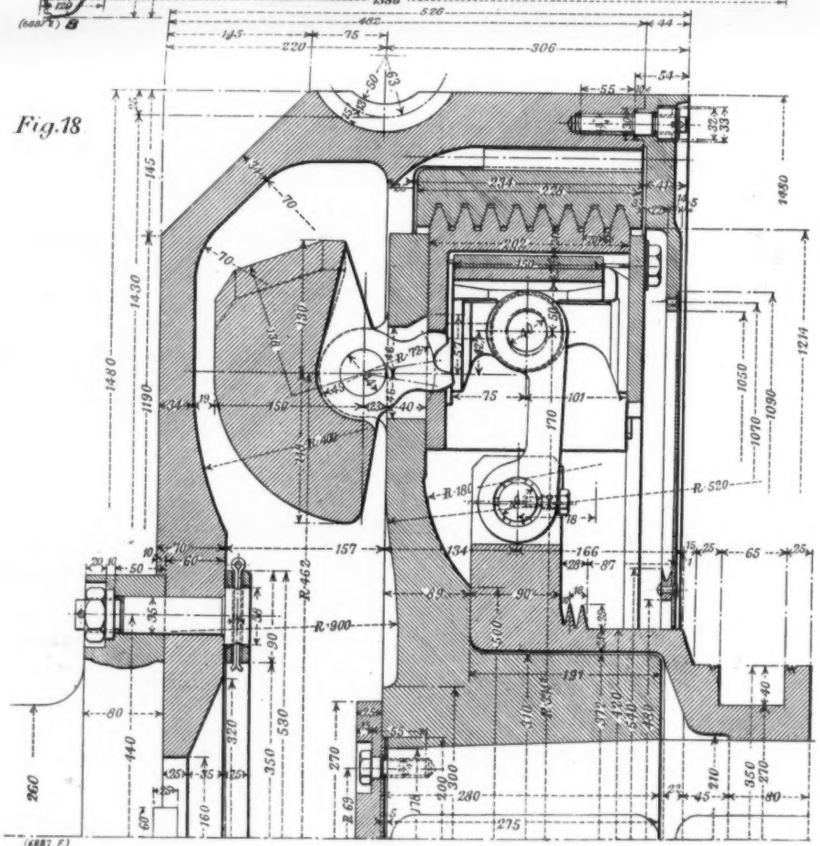


Fig. 18
(6887 F.)

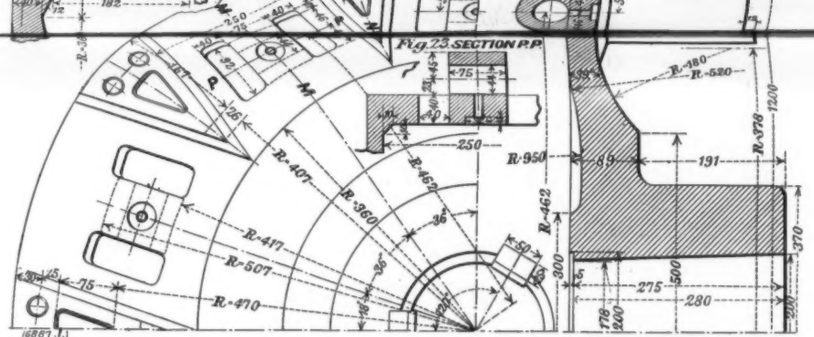


Fig. 23. SECTION P.P.
(6887 I.)

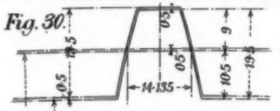


Fig. 30.

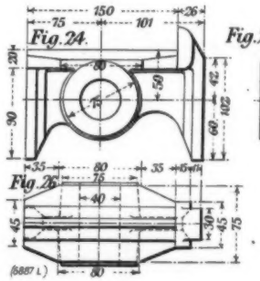


Fig. 24.
Fig. 26.
(6887 L)

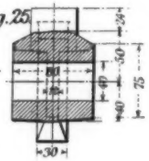


Fig. 25.

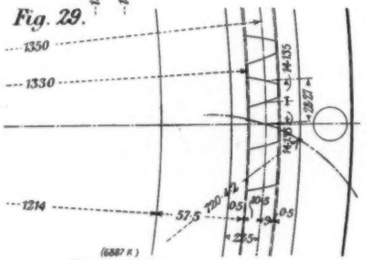


Fig. 29.
(6887 K)

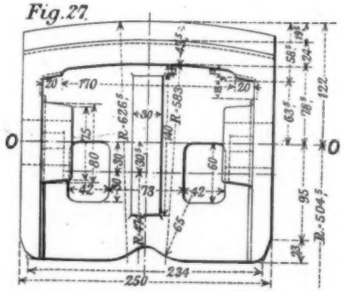


Fig. 27.

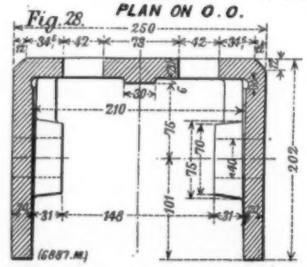


Fig. 28.
PLAN ON O.O.
(6887 M)

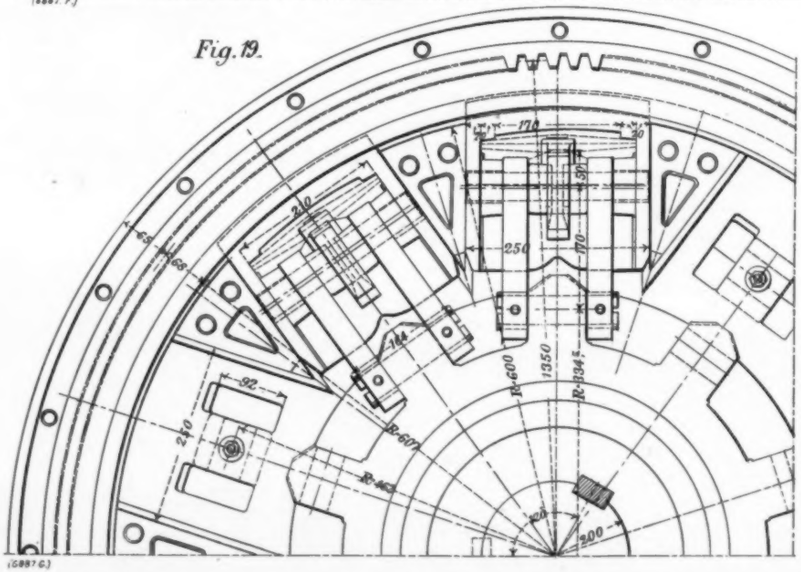


Fig. 19.
(6887 G.)

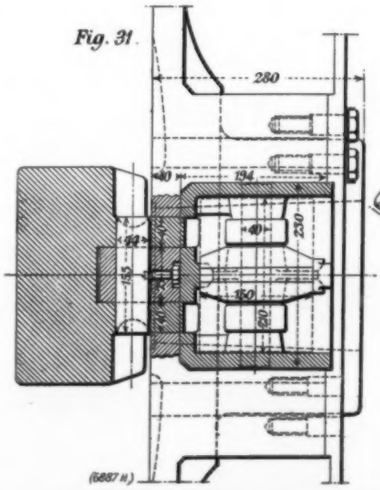


Fig. 31.
(6887 H.)

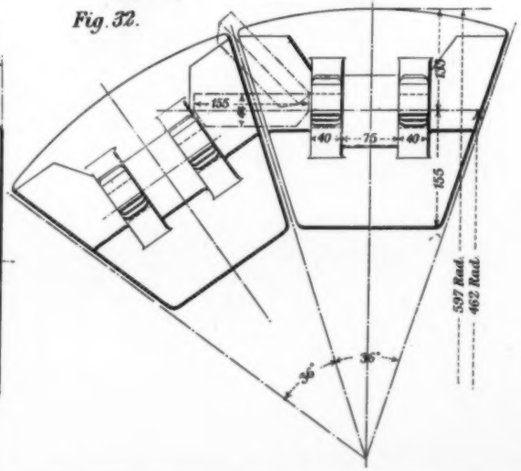
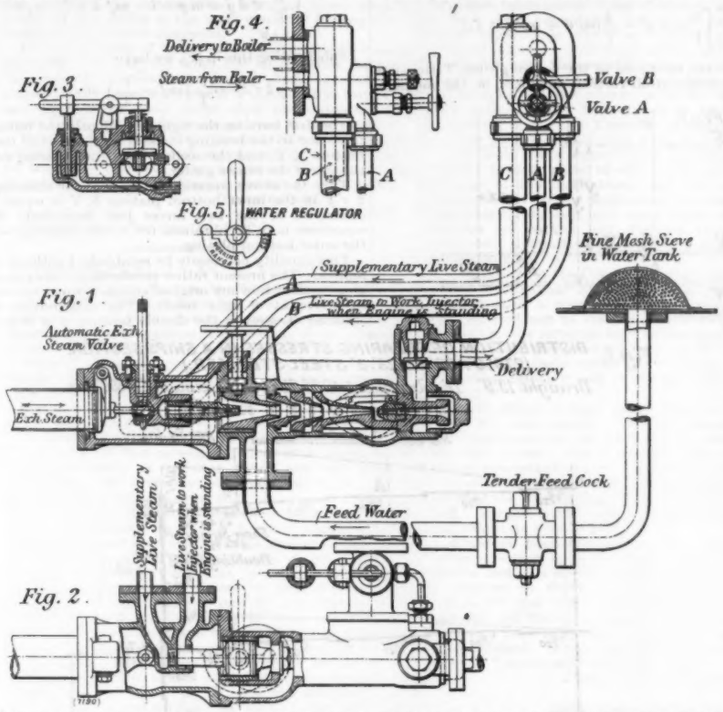


Fig. 32.
597 Rad.
462 Rad.

EXHAUST STEAM INJECTOR FOR LOCOMOTIVES.

CONSTRUCTED BY MESSRS. DAVIES AND METCALFE, LIMITED, ENGINEERS, ROMILEY.



screw driven by spur wheels from the handwheel spindle, as will be clear from the illustrations. The design of the spur-reduction gear and rocking lever calls for no particular comment, but the method of lubricating the collar, which can easily be followed from the details of this part shown in Figs. 14 to 17, should be noted. Oil is delivered through a flexible pipe from a lubricator mounted on the bulkhead to a groove in the collar which distributes it to the three working faces; surplus oil is drained away through an outlet at the bottom shown in Fig. 14.

Before describing the clutch in detail, we should first explain that one of its special features is the provision of balance weights to counteract the effects of centrifugal force on the radially moving parts by means of which the coupling between the engine and propeller shafts is effected. This feature, of course, prevents the pressure between the friction surfaces from becoming excessive at high speeds, and also facilitates their disengagement. Another very important point is that the power is transmitted from one part of the clutch to the other through a loose ring, on the outer surface of which involute teeth are cut. These engage with similar teeth cut on the inner surface of the clutch body, and thus a certain amount of longitudinal movement between the clutch parts is possible at all times. Slight relative movement is also possible in a radial direction, since a certain amount of clearance is left between the teeth. The clutch body is thus relieved of strain which would otherwise result from a slight inaccuracy in the alignment of the engine and propeller shafts, as well as from vibrations of the engine or propeller.

The best idea of the general design of the clutch will be obtained from an examination of the half longitudinal section reproduced in Fig. 18, together with the part elevation given in Fig. 19. The latter, it should be explained, is a view looking forward with the cover removed. The clutch body, shown in Fig. 18, is a cup shaped casting of high-tensile cast iron bolted on to a flange on the crank shaft. The other main part is a disc-shaped steel casting with a central boss keyed on to the tapered end of the propeller shaft. Details of this part are illustrated in Figs. 20 to 23, and from these it will be seen that the outer face is formed with ten triangular cheeks. These cheeks form parallel-sided radial grooves in which the ten internal friction members slide. The latter are kept in position by means of a forged steel cover ring, and this ring, which is shown in Figs. 18 and 22, also helps to support the cheeks to which it is attached by studs. We may here mention that to test the strength of the main driven members, a pair of them, constructed of cast iron, were placed face to face and subjected to a static torque equivalent to the transmission of 66,000 h.p. at 330 r.p.m., without any of the cheeks cracking, although the steel supporting rings were not in position. Some experiments were also made to ascertain the bursting velocity of the clutch body constructed completely of cast iron, and for this purpose a clutch was tested in a shaft in the ground. It was driven by a 50 h.p. Fiat motor through a vertical shaft and was found to burst at a peripheral speed of 121 metres (397 ft.) per second. In similar trials, made on small steel models, the bursting velocity obtained was only about three-fourths of the above-mentioned figure.

Each friction member is moved radially by a pair of toggle levers mounted on the sliding sleeve, which is also a casting of high-tensile iron. The arrangement of the toggle levers is clearly shown in Figs. 18 and 19, and from the latter it should be noticed that the pin carried by the pair of toggle levers is a loose fit in the holes formed in the boss of the sliding friction member. The reason for this is that the pressure from the toggles is transmitted to each of the sliding friction parts through a crosshead and a pair of plate springs. The crosshead, details of which are given in Figs. 24 to 26, is mounted on the pin between the two toggle levers, and the springs are fitted in between this crosshead and the sliding friction member, as indicated by dotted lines in Fig. 19. The springs, which are also shown in section in Fig. 18, are rectangular in plan, but are of tapering section from the centres to the edges, as will be clear from Fig. 19. One of the friction members is illustrated separately in Figs. 27 and 28, the former being an elevation looking forward and the latter a sectional plan in the plane of the toggle pin. They are castings of high-tensile iron formed with circumferential ridges on their outer surfaces, which engage with corresponding grooves in the inner surface of the loose ring above referred to; the arrangement will be clear from an inspection of Fig. 18. The ring, which is of cast steel, is kept in place by a cover of the same material attached to the clutch body by means of studs. Details of the involute teeth cut on the outer surface of the ring and through which the torque is transmitted as previously mentioned, are given in Figs. 29 and 30, and the latter shows the clearances provided to allow slight radial and longitudinal movements between the driving and driven shafts.

The only details of the clutch which now remain to be described are the balance weights used to counteract the effects of centrifugal force on the sliding friction members. These weights are shown separately in Figs. 31 and 32, and their design and arrangement can easily be followed by examining these illustrations in conjunction with Fig. 18. They are constructed of plain cast iron, and are mounted on pins carried by lugs formed on the cast-steel disc which constitutes the main driven member of the clutch; the pins are secured by set-screws shown in Fig. 31. Two short arms formed on each balance weight fit into slots in the sliding friction members, as is most clearly shown in Fig. 18, so that the force on the weights acting radially outwards is made to exert a pressure in an inward direction on the friction members. In this way the pressure between the friction surfaces is rendered independent of the speed of rotation.

Ample lubrication is provided by partially filling the clutch body with oil, which, of course, collects round the circumference of the body when the clutch is running and completely immerses the whole of the working parts; when the clutch is at rest, the oil is retained by the steel plate cover shown on the right of Fig. 18. It is probably largely due to the effective lubrication that the makers are able to guarantee the clutches for five years' continuous service.

In conclusion, we may mention that in clutches of this type designed for high powers and high speeds, balance weights are provided on both sides of the sliding members to render the forces acting on the latter quite symmetrical. For this purpose, the main driven member of the clutch is made in two parts, between which the sliding members work. The inner ends of the toggle levers are then pivoted on to a ring placed between the two main members and operated by means of rods connected to the sliding sleeve through holes in one of the main driven members. This design is the subject of British patent number 149,068, while the use of toothed gearing for the connection of clutch parts and the method of lubrication above described are covered by patent specification No. 141,196.

METCALFE'S EXHAUST STEAM INJECTOR.

IT will probably surprise many engineers to be told that the exhaust steam injector dates back to 1876, for, although there are over 5,000 locomotives to-day on which this excellent device is used, its general adoption is not of very old standing. The original exhaust injector was capable of feeding against boiler pressures up to about 70 lb. per square inch. This was subsequently improved upon and in the type "D" which was described in these columns in vol. xc, page 859, the appliance had been made capable of feeding against 120 lb. per square inch. For higher pressures than this it was necessary to use supplementary live steam in order to feed into the boiler.

A further step has now been taken by Messrs. Davies and Metcalfe, Limited, of Romiley, the makers, who have introduced still another modification which we illustrate in Figs. 1 to 5 herewith. The result of this is that the new pattern is capable of delivering water against a pressure of 150 lb. per square inch, with one pound exhaust pressure, thus greatly reducing the amount of live steam necessary to get up to the normal working pressures in locomotive practice. The injector is well shown in the vertical longitudinal section, Fig. 1, and the part sectional plan, Fig. 2. Exhaust steam is drawn from the cylinder casting, or base of the blast pipe, as formerly, and passed through a stocking oil separator. This detail is not changed in the new pattern and is therefore not illustrated, being by now familiar to all locomotive engineers.

In the present design the greater efficiency is due mainly to the introduction of an additional nozzle which brings the steam into more effective contact with the stream of water. There are in all six nozzles or cones. Starting from the left hand end at which the exhaust steam enters, the first nozzle is that for the supplementary live steam. The next large cone is the exhaust nozzle. This is followed by the draught tube, which, it will be observed, is in communication with the water supply. The combined stream of steam and water flow from here through another nozzle which is termed the vacuum tube. In this cone additional exhaust steam is introduced to the stream, being supplied through a by-pass shown in the plan, Fig. 2. Leaving this cone the stream passes to the combining nozzle which is of the flap type, and thence to the delivery and through a back pressure valve to the boiler feed pipe and clack. The new nozzle introduced is that designated the vacuum tube. Its effect is to give a much better lead to the stream, between the draught tube and combining nozzle, than formerly, and to cause the supplementary exhaust steam to mix much better with the water, thus raising the velocity of the stream entering the combining nozzle. In working we understand a vacuum is caused in the chamber between the vacuum nozzle and the combining nozzle. With this injector as already stated, with 1 lb. of exhaust pressure, feed can be delivered against 150 lb. With 5 lb. exhaust it can deliver against 180 lb. The supplementary live steam has thus to overcome a much smaller balance against the injector than formerly, and the amount is correspondingly reduced. It is stated now to have been reduced by about 40 per cent., and to amount to less than 2½ per cent. of the evaporation of the boiler. The feed is delivered at between 200 deg. and 220 deg. F.

The supplementary live steam nozzle, combined as

shown in Fig. 2, with a live-steam nozzle for operating the injector when the engine is standing, is the same in this "F" pattern injector as in the former "D" type. The exhaust steam valve, and cam lock are likewise similar. The water regulation, effected by sliding the exhaust steam nozzle lengthwise in the barrel, by means of an eccentric on a vertical spindle, is also the same as before, while the combined steam and clack mounting, Fig. 4, has not been changed in design. The "F" pattern is, however, fitted with an overflow valve, which is different from the former model. This is illustrated in Fig. 3. It will be noticed the valve is provided with a stem over which is extended one arm of a short lever. The other arm of this lever is connected with a plunger or piston, the space on the underside of this being in communication with the delivery end of the injector, *i.e.*, being under pressure when the injector is working. Thus, before the injector has started, the valve is free to allow water to escape, but when it has picked up, the valve is held down by the lever, and air is prevented from entering. The action is very prompt.

"SHEARING STRESSES IN SHIP STRUCTURES."

To the Editor of Engineering.

Sir,—I wish to make a correction in my paper entitled "On Shearing Stress in a ship's Structure," which was published in Engineering, vol. xciv (1912), page 894, and I shall feel obliged if you will spare space for this in your paper. In describing a method for computing the shearing stress in the double bottom of a ship, I gave an equation

$$\frac{F}{I}\, i = 2\,\tau'\,t'\,y + 2\,\tau\,t\,y$$

as a necessary condition for the equilibrium of the couples due to the stresses in a H-shaped part of a double bottom (X Y Z W in the annexed diagram, Fig. 1). In this equation, however, I find that I overlooked one of the couples acting on the part under consideration; this being the couple due to the shearing stresses in the consecutive transverse section (shown by R in Fig. 1). This couple must be introduced in the above equation of equilibrium.

Now, on account of the equality of shearing stresses in a pair of planes at right angles to each other, we have

$$R = \frac{F\,M}{I\,T},$$

in which M is the moment of the sectional area about the neutral axis of the ship's section of all double-bottom members lying above or below the horizontal line passing through the point under consideration (say, line H L in Fig. 2), according as the point lies above or below the lower edge of the marginal plate; and T the horizontal or collective thickness of double bottom members along the horizontal line H L according as H L cuts horizontal or vertical members, whilst F denotes the shearing force on the ship along the section and I the moment of inertia of the ship's section about its neutral axis.

Therefore, the couple due to R acting on the part X Y Z W (Fig. 1), which has a longitudinal thickness Δx is

$$\Delta x \int \frac{F\,M}{I\,T}\, t''\, d\,y,$$

where t'' is the horizontal thickness of the H-shaped portion X Y Z W. Thus the correct equation should be

$$\frac{F}{I}\, i = 2\,\tau'\,t'\,y' + 2\,\tau\,t\,y - \int_{XYZW} \frac{F\,M}{I\,T}\, t''\, d\,y$$

$$= 2\,\tau'\,t'\,y' + 2\,\tau\,t\,y - \frac{F}{I}\int_{XYZW} \frac{M}{T}\, t''\, d\,y.$$

Substituting this in the equation for the equilibrium of forces in a longitudinal direction, namely:

$$\frac{F}{I}\, m = 2\,\tau'\,t' + 2\,\tau\,t,$$

in which m is the moment of the sectional area of the part X Y Z W about the neutral axis of the ship's section, we have

$$\frac{F}{I}\, i = \frac{F}{I}\, m\, y - 2\,\tau'\,t'\,(y - y') - \frac{F}{I}\int \frac{M}{T}\, t''\, d\,y.$$

Now put $y - y' =$ the depth of the double bottom $= d$, then we may write

$$2\,\tau'\,t' = \frac{F}{I}\,\frac{1}{d}\left(m\,y - i - \int \frac{M}{T}\, t''\, d\,y\right) \quad . \quad (1)$$

The last term on the right may be integrated as the sum of three separate integrations as follows:—

(*a*) Integration over the part X Y of the inner bottom plating. By the elements of the integral calculus, we have

$$\int \frac{M}{T}\, t''\, d\,y = \frac{b}{B}\,(m_i\,y' - i'_i)$$

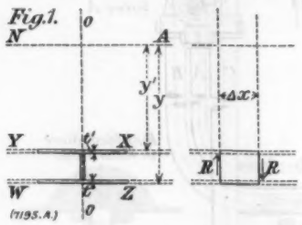
in which m_i and i_i are respectively the moment and moment of inertia of the area of the whole inner bottom plating about the neutral axis of the ship's section, y' the distance of the lower surface of the inner bottom plating from the neutral axis, and b and B respectively the breadths of X Y and the full breadth of the inner bottom plating.

(*b*) Integration over the centre girder.

In a similar way, we have

$$\int \frac{M}{T}\, t''\, d\,y = \frac{t}{T}\,(m_c\,d + m_c\,y - i'_c)$$

where t is the thickness of the centre girder, T the sum of the thickness of all vertical members, m_c the moment



of the area of all vertical members about the neutral axis of the ship's section, i_c the moment of inertia of the same about the same axis, and y the distance of the heel of the vertical members from the same axis (for sake of simplicity all y's are taken to be equal).

(*c*) Integration over the part W Z of the outer bottom plating, Fig. 1.

Supposing the bottom plating to be flat, we have

$$\int \frac{M}{T}\, t''\, d\,y = \frac{b}{B}\,(i'_b - m_b\,y)$$

in which i_b denotes the moment of inertia of the whole area of the outer bottom plating about the neutral axis of the ship's section, and m_b the moment of the area of the same about the same axis.

Collecting together (*a*), (*b*) and (*c*), and remembering that the last one has a contrary sign, we have

$$\int_{XYZW} \frac{M}{T}\, t''\, d\,y = \left\{\frac{b}{B}\,(m_i\,y' - i'_i) + \frac{t}{T}\,(m_c\,d + m_c\,y - i'_c) - \frac{b}{B}\,(i'_b - m_b\,y)\right\} \quad . \quad . \quad . \quad . \quad (2)$$

Now let m'_i, m'_c and m'_b denote respectively the moment of the area of X Y of the centre girder and of W Z about the neutral axis of the ship's section. Then evidently

$$\frac{b}{B}\, m_i = m'_i$$

$$\frac{t}{T}\, m_c = m'_c$$

$$\frac{b}{B}\, m_b = m'_b$$

and $m'_i + m'_c + m'_b = m$; similarly

$$\frac{b}{B}\, i_i + \frac{t}{T}\, i_c + \frac{b}{B}\, i_b = i,$$

Therefore, the equation (2) may be written:

$$\int_{XYZW} \frac{M}{T}\, t''\, d\,y = m\,y - i - m'_i\,d + \frac{t}{T}\, m_i\,d$$

Substituting this in (1), we have

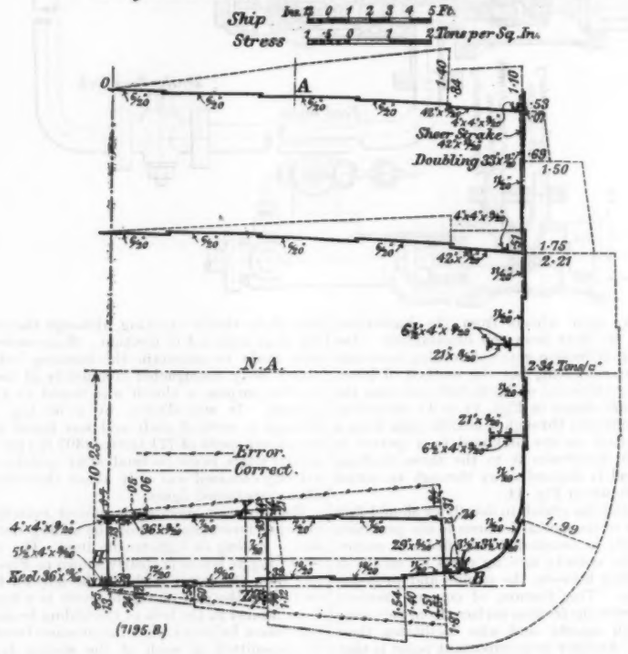
$$2\,\tau'\,t' = \frac{F}{I}\left(m'_i - \frac{t}{T}\right) m_i \quad . \quad . \quad . \quad (3)$$

The first term on the right is evidently the unbalanced force due to the bending stresses on the part of the inner bottom X Y, and the second term the shearing force on the top of the centre girder.

Thus the above equation shows that the shearing force $2\,\tau'\,t'$ in the inner bottom plating X Y is equal to the difference of the two forces just described. Similar equations may be obtained for τ, the shearing stress in the outer bottom plating.

This equality can easily be established without mathematics. The present rather cumbersome analysis merely aims to show how my original equation must be corrected to arrive at a right result. The distribution of the shearing stresses in the double bottom of a ship shown in my previous paper was re-calculated by the equation (3), and is shown in the appended diagram in which original curves are also retained for the sake of comparison.

Fig.2. DISTRIBUTION OF SHEARING STRESSES IN A SHIP'S SECTION. (279'.0'x39'.6'x23'.3' STEEL STEAMER.)
Draught 19'.9'. Displacement 4735 Tons. Maximum S.F. 590 Tons.



Yours, &c.,
K. Suyehiro.

Tokio, November 21, 1921.

"THE FLOW OF METAL DURING FORGING."

To the Editor of Engineering.

Sir,—It would have been enlightening to have heard more of the views of practical forgers on this subject so considerably commented on by Engineering of November 18.

Since being apprenticed at Crewe Works over 20 years ago when a forging press was first installed there, I have spent a career amongst hammers and presses, and must say that where plain cogging or flattening is concerned the resultant flow of metal and quality of forging appear much alike whether forged at a hammer or a press. No doubt when watching a press smoothly penetrating several inches of metal at one continuous stroke, whilst a hammer stroke may have a penetration of less than an inch with the attendant violent vibration, it would appear that the flowing of the metal looks much the easier at the press. But results in quality of the subsequent production hardly bear this out as greatly advantageous for straight forgings. With plain hammered forgings the time necessary for the flow of metal to reach the centre of the forging seems all sufficient for the purpose, providing a hammer of full power and weight capacity is employed. If the hammer is too light the power is expending itself on the outside portion of forging and the metal does not flow in the centre any more than it does in the centre of a forging to which an under-powered press is applied.

In the case of forgings made from ingots of several feet in diameter practical and mechanical advantages

favour the press apart from the question of flow of metal. When we come to forgings having deep shoulders or of shapes requiring abrupt displacement of metal the press often scores. The slow continuous stroke allows the metal at all points to adapt itself to streamline formation, whereas the intermittent hammer blows tend to break the streamline at the weak corner of forging where metal has been over-displaced.

In case of some of the smaller forging presses coming gradually into use, say from 100 to 500 tons capacity, this seems not so much due to the advantageous flow of metal as to the ease with which it is possible to improvise and apply loose tools under slow press stroke which under sharp hammer blows would not be practicable.

Reverting back to the general comments on Mr. Massey's experiments and having since been privileged to see a copy of the paper, some of the experiments therein appear likely to become classics on the subject.

Yours faithfully,
W. J. HOUGH.

Gainsborough, January 16, 1922.

"ENGINEERING AS A PROFESSION."

TO THE EDITOR OF ENGINEERING.

SIR,—The correspondence on the above subject has interested me, but it appears to have developed from a general grievance against engineering as a profession to one of remuneration.

Several correspondents have cited their own particular case of hard work and low pay and made reference to other professions, but no one has put forward a reasonable solution to the problem. I doubt if engineering is worse than any other profession or trade. Speak to a doctor and he will tell you the medical profession is overcrowded and nowadays offers little scope for an ambitious man. A solicitor would say the same of his calling, and probably both men would be justified to a certain extent in saying so.

It is all very fine to grumble about 350*l.* per annum being a miserable sum to offer a young engineer, but at the present time how many, old as well as young, would welcome that salary and much less to get a job? I am one of those young (26), inexperienced electrical engineers out of an appointment, no income or influence, too proud to beg, unable to pay my subscription to the Institution, and striving hard to keep up the same appearance as when I was at college and in work, and I would willingly accept any salary that would be sufficient to keep me. When I was steeped in the mud of Flanders I used to dream of the bright future and how cheerfully I would accept all sorts of conditions should I be spared to put on my "civvy" clothes once more. How those dreams have been shattered! But I realise that if trade is bad work cannot be made nor wages paid.

I do not wish to dispute the technically trained engineer's claim to a better scale of pay, rather the opposite, but with unemployment so widespread the time is altogether inopportune for the discussion of or agitation against low wages. It always seems to me a kind of weakness to be always pointing out the defects, absurdities and injustices of any working system, as if it is something wicked and wonderful that such bad methods exist. The wonder is all the other way; it would be a miracle if all things went well, and it is those of us who are making the best of things during these trying times who are doing most gradually to improve and rectify matters. In spite of my position I am trying to joke and am constantly looking forward to the break of a new day. If, however, that day does not soon come I shall be compelled to wash the starch out of my collar and take any old job that comes along—road sweeping, if there is a vacancy, which isn't often, and then there is generally a waiting list—or use my only qualifications of swank and bluff to conceal my ignorance to obtain admission to a new profession.

Yours faithfully,
"ELECTRON."

January 17, 1922.

TO THE EDITOR OF ENGINEERING.

SIR,—As one who believes in the future of the engineering profession, and looks upon present conditions as necessarily transitory in that the world is living on the work of the great engineers of the past, and cannot, if civilisation is to endure, continue to do so indefinitely, I have read with interest the letters which you have published under the above heading and have been struck by the absence of anything of the nature of constructive proposals to secure for the profession in the future the recognition and status to which it is already fully entitled by reason of its past achievements.

A good deal has been said of the impotence of the professional institutions to take any effective measures in their members' interests, and it is pertinent to inquire why this should be so. In my view, it is largely, if not entirely, due to the past reluctance of the large majority of engineers themselves to do do anything for the advancement of the authority and prestige of the institutions to which they belong, or even to take the most casual interest in their affairs and management.

The result has inevitably been to stultify what I am convinced was one of the principal aims of their founders, to make them the *almae matres* of all members of the profession, under whose protection a real corporate spirit and a desire to help each other would have been developed. In the absence of such a common bond and of any genuine cohesion between members, it is not difficult to understand why the institutions have become more and more out of touch with their members, and the latter in turn less and less able to exert any effective influence on their administration and policy.

Further, the extraordinarily rapid enlargement of the scope of engineering during the last century has resulted in the dissection of the profession and institutions have been founded to look after each of the limbs. This would not necessarily be a bad thing in itself, but unfortunately there has been a tendency to forget that all engineering rests on the study and appreciation of the same fundamental laws of nature, and there seems to be a most lamentable lack of co-operation between these institutions even on questions of obviously common interest. The recent action of the "Civils" in connection with the registration of engineers will occur to all as a case in point. There have, however, been instances in the past where the ice has been broken and joint action taken. The report of Sir W. H. White's committee on "The Training of Engineers" can be cited as an example of good work thus accomplished.

One could make a good many suggestions for remedying the present state of affairs and for increasing the prestige of the institutions and their utility to their members and to the profession, but the questions are undoubtedly difficult and complicated, and seem rather matters for careful and detailed investigation by a competent committee than for the expression of individual opinion.

I suggest that the Councils of the Civils, Naval Architects, Mechanicals and Electricals get together and appoint such a committee. They would, I think, be well advised not to restrict membership to themselves but to provide for some representation of men who have still to make their way in the world. The profession seems particularly prone to overlook the possibility of finding talent round about the lower rungs of the ladder.

In all affairs a time comes when it is useful to sit down and take careful stock of a situation, to analyse the experience of the past and to endeavour to peer into the future. The economic effects of the war, the labour movement, recent legislation in connection with education, and the growth of specialization have probably affected the engineering profession more than any other, and I suggest a little deep thinking could do no harm and might do a lot of good.

American engineers have during the last few years taken effective steps to secure the future of their profession and it is up to British engineers to do the same. I venture to think that if "Corporate Members," "B.Sc.'s" and others would write to their institutions and demand the appointment of a committee of enquiry such as I have ventured to propose, something might be accomplished. Wringing one's hands and crying "Woe unto us" never achieved anything.

I am, Sir, yours faithfully,
"NABLA."

EXPLOSION OF A FEED-WATER HEATER.

A PRELIMINARY inquiry under the provisions of the Boiler Explosion Acts, 1882 and 1890, has been conducted by the Board of Trade relative to the explosion of a feed-water heater which occurred on July 28 last at Newfield Brick Works, Willington, Durham, the owners of the works being Messrs. Bolckow, Vaughan and Co., Limited. The report of the Surveyor on his examination of the exploded heater has been issued by the Board of Trade, and from it we take the following particulars:—

The feed-water heater was a rectangular cast-iron vessel, its internal dimensions being 3 ft. 9¼ in. long, 2 ft. 7¼ in. wide, and 2 ft. 8 in. deep. The top, back and sides were 1 in. in thickness, and the thickness of the bottom varied from 1 in. to ¾ in. A division plate was cast with the vessel, attached to the top and back, but clear of the bottom by 6¼ in. A door was fitted on the front of the heater and secured by means of 27 ¾ in. studs and nuts. The thickness of the body of the door was ⅞ in., and the flange was 1¼ in. thick. A sludge hole was cast below the door, and an oil trap was cast on the side of the heater, each fitted with inspection doors. The only mountings on the heater were one ¾ in. steam inlet, one ½ in. drain cock, and one steam gauge connection. All the other openings in the heater were blanked off.

The heater was fitted at the works some time prior to 1915, but the date of fitting or the name of the maker could not be ascertained. No repairs had been made, and the heater had not been inspected periodically by any person or society. It was last inspected by the millwright at the works on July 27, 1921. It was not insured.

When the explosion occurred, the bottom, side and half of the door were blown out. The heater was forced from its seating and deposited about 2 ft. away from its original position. The door of the pump-room was blown out and a portion of the roof displaced. Foster, the millwright, and an apprentice were scalded and otherwise injured.

The explosion was caused by the bottom of the heater fracturing along its line of least strength, due to overpressure of steam.

In his "General Remarks" addressed to the Board of Trade in his report, Mr. McAuslan, the Surveyor, who examined the exploded vessel, states that it had been installed originally at the works for heating the boiler feed-water by means of exhaust steam from an electric power station, and also for separating out the oil contained in the exhaust steam. It had not been used for any purpose since the year 1915, but about June 17 last, Mr. Bagley, the consulting engineer to Messrs. Bolckow, Vaughan and Co., suggested to Mr. Gregory, the manager at the brickworks, that the quality of the silica bricks made there might be improved were they steam-dried before firing them in the kiln, and that a suitable steam pressure for the purpose would be about 80 lb. per square inch. In order to carry out the experiment, Mr. Gregory instructed the works engineer to see if there was any vessel in the works suitable for containing a few bricks, and the works engineer suggested the use of the disused feed-water heater, subject to the approval of Mr. Bagley. The works manager, Mr. Gregory, gave instructions for the heater to be made ready for carrying out the experiment, and, as the works engineer was about to go on leave, the work of preparation was done by the millwright, assisted by an apprentice. The preparation consisted of disconnecting the old feed-water pipes and exhaust steam pipe connections and removing the air relief valve, fitting blank flanges over these openings, and fitting a ¾ in. diameter steam pipe inlet, a ½ in. diameter drain pipe connection, and a steam gauge connection. No valve of any kind was fitted for relieving the vessel of excess pressure. On July 27 these preparations were completed, and, with the door off, six bricks were placed inside the heater. It was then brought to the notice of Mr. Bagley in a general way, and as he did not dissent from its being used for the experiment, the manager and the millwright apparently concluded it was in all respects satisfactory; but the question of the strength of the tank was not raised by anyone, nor was Mr. Bagley's opinion on that point asked for. The door was jointed up, and on July 28 the millwright turned on the steam, leaving the drain cock open, for the purpose of thoroughly heating the vessel. At noon steam was shut off, and about 12.40 p.m. it was again turned on. About 12.50 the drain cock was shut and the steam pressure rose to about 50 lb. per square inch on the gauge at 1 p.m., when the explosion occurred without warning, injuring the millwright and the boy, as stated above.

This, Mr. McAuslan says, "is a case where too much appears to have been taken for granted. No one questioned the strength of the heater, and no steps were taken to ascertain its actual strength or what pressure of steam it was fit safely to withstand. The facts that it made a suitable receptacle for a few firebricks, and was adjacent to the boiler steam pipe line, appear to have been the only points considered in reference to its use. Mr. Gregory stated that he relied upon Mr. Bagley's judgment and knowledge as to the suitability of the heater for the purpose of the experiment, and Mr. Bagley stated that he was relying on the practical knowledge of the local engineer; whereas, in fact, they neither had actually examined the heater. Mr. Foster, the millwright, who was the only one who actually inspected the heater, stated that he thought it was quite strong enough to carry the full boiler pressure, but he had made no calculations to ascertain its strength, nor had he tested it in any way before turning on the steam. He further stated that he had got no instructions as to what pressure of steam was to be used, nor as to turning on the steam, but he had assumed that the heater was fit to stand the full boiler pressure of 80 lb. per square inch, as the steam was to be taken from the boilers at that pressure." Mr. McAuslan concludes by saying, "It is a fortunate circumstance that the heater did not contain a large volume of water at the time of the explosion, or the results would have been much more serious than they were."

In his "Observations," Mr. Carlton, the Engineer Surveyor-in-Chief to the Board of Trade, sums up as follows: "This report deals with an explosion from a rectangular cast-iron vessel which was being used for experimental purposes. Apparently no consideration had been given to its sufficiency for the steam pressure to which it was to be subjected, each of the responsible higher officials assuming that someone else had taken the necessary measures for safety. The vessel burst with considerable violence at a pressure lower than that at which it was intended to be used."

"It is very fortunate," Mr. Carlton adds, "that in these circumstances the injured men escaped as lightly as they did."

BRITISH IRON AND STEEL PRODUCTION.—The production of pig-iron in December amounted to 275,000 tons, a figure slightly in excess of the production in November, when it was 271,800 tons. The furnaces in blast at the end of December numbered 77, compared with 85 at the end of November, 15 furnaces having gone out of blast during the month and 7 being re-lit. The production of pig-iron for the year amounted to 2,611,400 tons, compared with 8,007,900 tons in 1920. This figure is lower than in any year since 1850, when the production of pig-iron amounted to 2,249,000 tons. Of the production of pig-iron in December, 92,400 tons were hematite, 81,500 tons were basic, 13,800 tons were forge, and 78,600 tons were foundry. The production of steel ingots and castings in December amounted to 381,000 tons, or 62,000 tons less than November. The total production of steel for the year amounted to 3,624,800 tons, compared with 9,056,800 in 1920.

RAILWAY CARRIAGES AND WAGONS FOR THE ARGENTINE REPUBLIC.—A telegram has been received at the Department of Overseas Trade from the Commercial Secretary to H.M. Legation at Buenos Aires to the effect that the Argentine State Railways are calling for tenders to be presented by March 1 for 750 light narrow gauge goods trucks, cattle trucks and passenger coaches. Tenders must be presented through the local agent and three years' credit is asked for. The Commercial Secretary is sending on specifications (presumably in Spanish), and these, when received, will be available for inspection at the department. Attention is drawn to the export credits scheme, which provides financial facilities for giving extended credits. Copies of the regulations can be obtained from the Export Credits Department, 73, Basinghall-street, E.C., or can be seen in the *Board of Trade Journal* for November 24, 1921. The department will be pleased to suggest the names of Buenos Aires firms, with London offices, through whom tenders might be presented.

THE FLEXALA AND RESILINE PUMPS.

We have frequently in these columns described forms of pumps specially intended to deal with corrosive liquids, and now illustrate in Figs. 1 to 3, below, three types which contain features quite distinct from the ordinary centrifugal. The three pumps illustrated are of two main types, Figs. 1 and 2 being known as Flexala pumps, while Fig. 3 illustrates

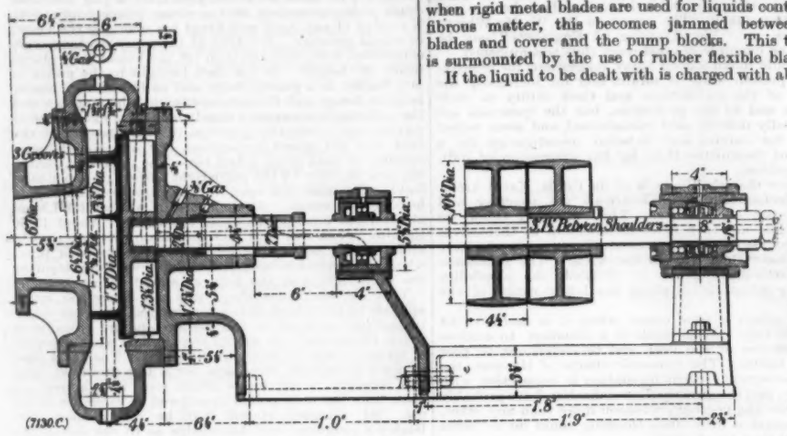


FIG. 1.

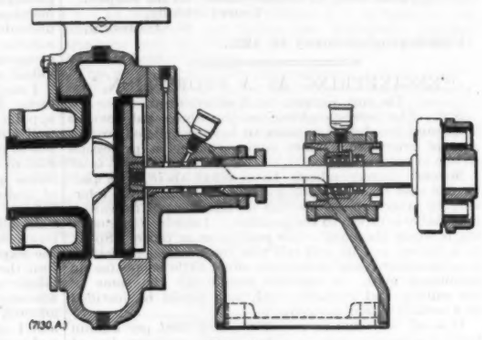


FIG. 2.

a pattern to which has been given the name of Resiline. The names are due to the inventor of the pumps, the Hon. R. C. Parsons, who has devoted a considerable amount of attention to the development of special forms of centrifugal pumps. The present machines are manufactured by Messrs. Metal Powders, Limited, at their St. Anne's Engineering Works, Clapham.

The feature of these pumps, as their names imply, is a flexibility and resilience in certain parts which tend to reduce erosion and corrosion when dealing with acids or liquids holding solids or fibrous matters in suspension. Not only are the pumps protected against erosion and corrosion so that they remain efficient for long periods, but they are sufficiently flexible in construction to encounter and deal with stones of moderate size without harm. The pumps are of the single inlet type, with balancing vanes at the back of the impeller. The three patterns illustrated are for different services. The simplest form is the Flexala pump shown in Fig. 1, from which it will be seen that this pump has an impeller which consists of a flat circular plate to the front of which is firmly attached, by vulcanisation, a coating of pliant rubber, out of which, and in one with which, spring the curved rubber blades of the impeller, the outer edges of which are unshrouded. The impeller is set by means of an adjustable thrust bearing so that the edges of the blades always move in close proximity to the front cover. The inner face of this cover has spiral grooves formed in it, in the direction in which the stream of water flows through the pump. The pump casing is of the ordinary volute type terminating in a diverging outlet.

——	Resiline.	Metal.
	£	£
Interest and amortisation; including one set of spare parts, 10 per cent. on capital	35	23
Upkeep—		
Suction cover ..	5·85 ×365/100=21	2·625×365/15= 64
Impeller	6·625×365/68 =35	4·00 ×365/15= 95
Volute	7·95 ×365/135=21 (not worn out)	6·50 ×365/20=118
Minimum cost, one year's repairs ..	£77	£277
Total yearly cost ..	£1 2	£300

The rubber employed is of a specially pliant and tough quality, which is extremely resistant to erosion. It is well known, for instance, that rubber will withstand sand blast for a considerable period without exhibiting signs of destruction. Similarly it may be remarked that the rubber of motor vehicle tyres is more enduring than the metal studs often inserted in them. It has been found possible in ordinary work to make the vanes of the required stiffness to resist satisfactorily the forces of impact of the liquid pumped, whilst those due to centrifugal action are practically inoperative owing to the specific gravity of indiarubber being practically the same as that of water.

The action of the vanes and spiral grooves assists the pump in handling fibrous substances or small solids. If fibrous material when passing through the pump gets between the cover and the vanes, the spiral grooves prevent it rotating with the impeller, and the vanes bend momentarily and pass over the obstacle without reducing the flow of liquid through the pump. When freed the fibres are carried on by the current and discharged by the pump. The action is, of course, similar to that of the squeegee. As is well known, when rigid metal blades are used for liquids containing fibrous matter, this becomes jammed between the blades and cover and the pump blocks. This trouble is surmounted by the use of rubber flexible blades.

If the liquid to be dealt with is charged with abrasive matter further protection may be provided by coating the inside of the cover with rubber, as in the Flexala pump shown in Fig. 2. This rubber protection is vulcanised on to the casting, and spiral grooves are formed on the inner face of this material similar to and for the same purpose as those described in connection with the form previously mentioned.

Should the liquid to be handled contain corrosive chemicals in addition to erosive matter, as in many mining operations, the Resiline pump, Fig. 3, should be adopted instead of the Flexala patterns. In this pump the rubber protection is extended to the whole of the interior of the pump, the casing and impeller being both completely lined with pliant rubber, so that no metal is exposed. In mining operations, when dealing with slimes, &c., the liquid is so highly charged with solid matter that its specific gravity is sometimes 1·25, when the impact against the vanes is severe. For such work it is necessary to use an impeller in which the vanes are reinforced by the insertion of canvas. Vanes constructed in this manner retain the necessary flexibility to enable them to deal with fibrous material in the liquid pumped. For working with liquids which contain fibrous or solid material a special suction has been developed, illustrated in Fig. 4. This long slot orifice presents no obstruction to particles of a size which the pump can handle, but excludes matter too large to pass through the pump passages.

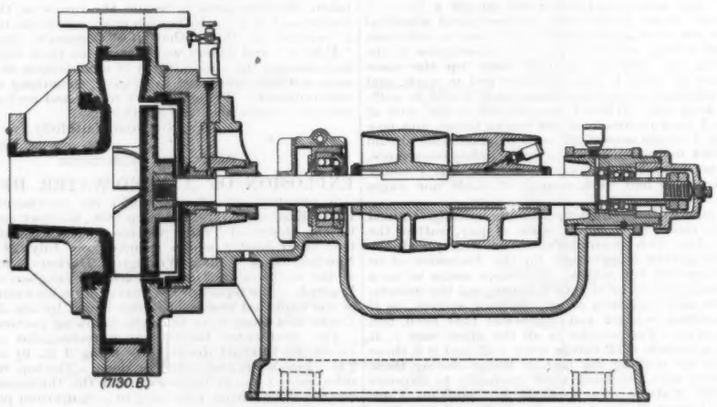


FIG. 3.

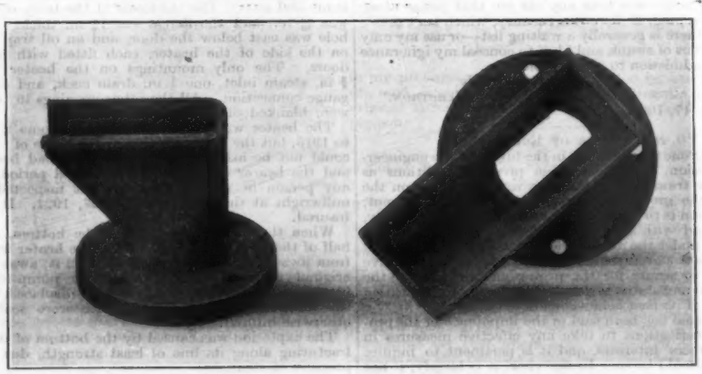
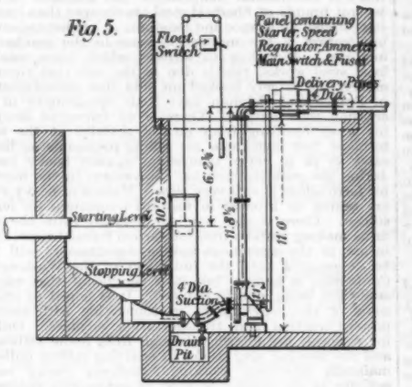


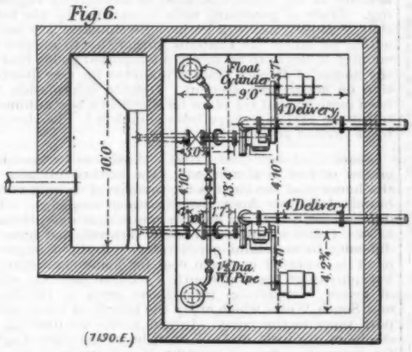
FIG. 4. SUCTION NOZZLE FOR USE WITH LIQUID CONTAINING FIBROUS SUBSTANCES.

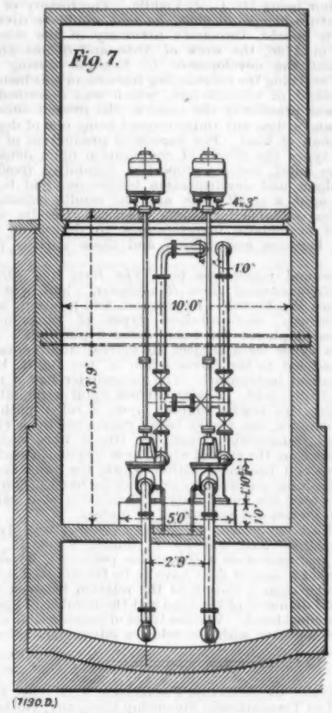
An example of service given by a Resiline pump is quoted in the table on the first column on this page. A Resiline pump is compared with an ordinary centrifugal, handling slimes on the Rand mines, where much trouble has arisen from the abrasive action of the sharp particles of quartz on the metal surfaces of the ordinary pump. The figures cover a period which is said to have been sufficiently long for a very good idea to be secured of the durability of the rubber protection. The rapid wear of centrifugals on this service

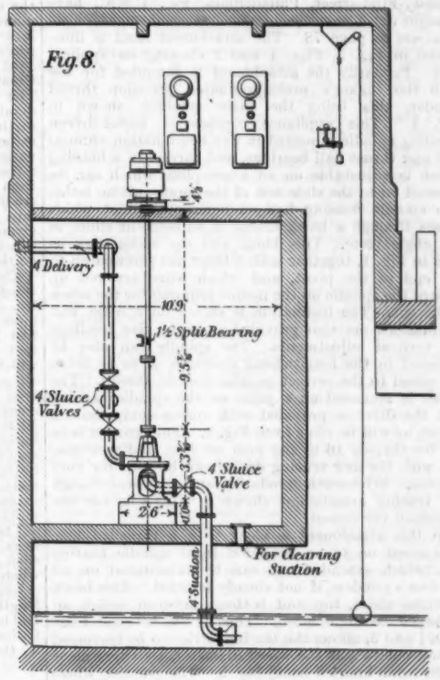
FLEXALA AND RESILINE PUMPS; AUTOMATIC INSTALLATIONS

MESSRS. METAL POWDERS, LIMITED, ENGINEERS, LONDON.









is common knowledge. The figures give the cost of one year's maintenance of a 5-in. Resiline pump, compared with an all-metal centrifugal.

In Figs. 5 to 8, on this page, we show two typical installations of pumps of these patterns. The first, illustrated in Figs. 5 and 6, is an installation of these pumps at the works of Messrs. Kynoch, Limited, Birmingham, employed for lifting unscreened sewage heavily charged with acid from pickling tanks. This plant has worked satisfactorily now for five years. The two pumps are belt-driven from electric motors at ground level. Starting and stopping is automatic, and controlled by a float, the action of which will be evident from our drawings.

The other illustrations, Figs. 7 and 8, show an installation arranged with Flexala pumps with vertical spindles. The installation shown is one of three at the new King George V Dock of the Port of London Authority.

Each set consists of two pumps, driven direct by overhead electric motors, at ground level, controlled again by a float in the well. The installation is entirely automatic and requires a minimum amount of attention.

At the works of The Magnesium Company, Wolverhampton, four Resiline pumps are in use for pumping a saturated solution of magnesium chloride containing in suspension 5 per cent. of native magnesite. The same firm has also two Flexala pumps in use for dealing with the same solution, but without the suspended solids.

SHOP MANAGEMENT.*

By Sir HENRY FOWLER, K.B.E. (Chief Mechanical Engineer, Midland Railway, Derby).

IN the question of shop management, probably the greatest change which has taken place, and one which I feel has never been discussed at any great length is the position of the shop foreman. With the greater attention which is now being paid to shop management and the speeding up so frequently of details of organisation, the position of the foreman has naturally, to a very great extent, changed from what it had used to be in older days. The changes which have taken place and the position which he now occupies depends very largely indeed upon the class of work which is being carried out. In times past undoubtedly the foreman was, to a very large extent, manager, whose particular business it was to control in every way the work that went on in the shop. He had the right of engaging, and discharging all the men who were in the shop, fixing all piece-work prices or payments by results, the ordering and receiving of material of all classes, and, to a great extent, the rates of pay to the various men under his control.

The position has, naturally, of recent years changed very materially. The first point, probably, which led to a change, was the standardisation of wages, which took not only out of the foreman's hands but also out of the hands of any one management, the question of the amounts to be paid to the various employees—the rates now being district ones. It is probable that in some shops and some works in which the shops are not of any large size, and the chief work carried out is that of repair, and where even the class of article required varies from day to day, the foreman still exercises, with the exception of the wages question, most of the authority which has been mentioned above. At the other end of the scale we have shops of considerable size where a single article only is made; and, in certain cases, where only certain portions of that article, perhaps are carried out, and where different conditions entirely pertain.

Men are engaged by the employment manager and allocated by him to the shops.

The materials are ordered and allocated to the shops by the order office. Machines for carrying out the operations are purchased after collaboration between the drawing office and the works engineer, and they are fixed in the shop by the works engineer's staff, their speed and feed being controlled by speed and feed experts. Progress of the work through the shops is governed by a planning department, its heating, ventilation and lighting being looked after by the welfare department, and any disciplining of the men has to be dealt with by the employment manager.

Piece work or premium prices are set and controlled by timers under the direct supervision of a special department, &c. Any question of dealing with labour or shop conditions is dealt with in conjunction with the shop committee. It is to this particular point that I shall draw attention in the discussion this evening, and I have thought it well in the first place to state two extreme cases. In the first case instanced, perhaps some one will say our friend is not a foreman but a manager, and probably another person may point out that in the latter case there is no room for the foreman. I think in that latter case a foreman might say that answer would be absolutely correct. In times past we have looked upon the foreman as being a representative of the management in the shop, whom the workman looks upon as being the visible sign of his employer, and I think we shall agree that it is absolutely necessary that this feeling should continue.

Each shop must be entirely judged on its own particular standpoint, but in all cases where any change is to be made every effort should be exercised to carry the foreman with the management: but it is only human that we none of us like to have work or position taken from us, and there undoubtedly arise cases in certain shops where details such as those mentioned are much better handled by an expert. I feel that in all cases the discipline of men, except as far as punishment is concerned, should be carried out by the foreman, and that he should be consulted before any material change is made in the shop or any alteration in operation in the shop; further that, as far as possible, all instructions should be given through him, in fact everything that can be done should be done to strengthen rather than depreciate his position whilst at the same time advantage is taken of the particular knowledge of which the special inspectors possess on various points.

I came across the following definition of tact the other day, and although it may not be absolutely correct I think it puts in a fairly concise form the best definition I have seen. It is as follows: "Tact is a science of the feelings, a considered method whereby a man's judgment may be overruled. It is a deference to the sensibility of man rather than to his intellect. Who, then, is bold enough to say that men are guided by their judgment rather than by their feelings? Were this so we should have no place for tact." It is this want of deference to the sensibilities of men that causes so many otherwise fully qualified men to be so unsuitable for management in any firm. Before I had seen the other definition I had said that tact may perhaps be taken as quick realisation of the other man's character and point of view.

By training and education we may force a man to be industrious, to possess technical knowledge, to see the advantage and necessities of loyalty both up and down, to cultivate the quickness of view and of thought, but we must have a good basis of tact in character, and also of imagination if we are to get the best results from a foreman.

Some time ago I saw it stated that one of the greatest benefits of holidays was to allow us to try various men as foremen and assistant foremen, and I think this is absolutely the case. We all of us know of instances where a man, as far as we could judge, gave promise of becoming a most excellent foreman, and yet we find when he is put into a position of authority he does not rise to it.

The position of under-foremen follows very largely in the remarks above. One trouble however, is with regard to the management keeping in touch with these men. It is a matter of very considerable difficulty as when in the shop one naturally deals with the head foreman, and although when the latter is absent the opportunity is given, yet I feel that in addition to this every effort should be made to see them and to encourage them in their work.

The coming of works' committees has made a considerable change in the relation of the foremen and men under him. Where these committees are of a formal nature, the foremen must be represented when discussions take place on subjects pertaining to their own shops. They must be made to appreciate that the discussions are on and along broad lines, and must feel that the shop committees have not been established in any way with a view of their being derogatory to their prerogative.

* Note (slightly abridged) to open discussion at the Manchester Association of Engineers, January 13, 1922.

WHEEL-TRUEING ATTACHMENT FOR SCREW-THREAD GRINDING.

IN connection with screw-thread grinding which has become popular in recent years, the Precision and Thread Grinder Manufacturing Company, of 1, South Twenty-First-street, Philadelphia, Pa., U.S.A., have brought out a new wheel-trueing attachment which we illustrate on page 78. The attachment itself is illustrated in Fig. 3, Figs. 1 and 2 showing its application. Primarily the attachment is intended for use with the maker's multi-graduated precision thread grinder, this being the little machine shown in Fig. 1. This appliance consists of motor-driven grinding spindle mounted in five combination annular and end thrust ball bearings, and carried in a housing which is adjustable on an angle plate which can be screwed on to the slide rest of the screw-cutting lathe. The spindle housing has an horizontal pivot which passes through a block fitting in adjustment slides in the angle plate. This block and the slides may be seen in Fig. 1, together with a large nut screwed on to the end of the pivot, and which when screwed up clamps the spindle on the incline required for the screw to be cut. The inclination is shown on a scale, and graduations are also provided so as to give readings for vertical adjustments. The spindle can also be adjusted in the longitudinal direction so as to bring the wheel to the correct position for the thread. The motor is mounted on a pillar on the spindle housing and the drive is provided with spring compensation above, as will be clear from Fig. 1. This grinder is in use for threads 16 to the inch on ⅛-in. and upwards, but with the new trueing device can be used for finer threads. Whitworth standards can be worked though the trueing attachment shown in Fig. 3 is for the American vee thread.

In this attachment a block with a threaded hole is screwed on to an extended front spindle bearing cap, which extended cap can be substituted on all the firm's grinders, if not already so fitted. This block provides slides, top and bottom, between which an L-shaped casting is fitted. This, as will be clear from Figs. 1 and 3, allows the trueing device to be traversed in and out to suit the wheel diameter, by adjustment of the small knurled head, Fig. 3. The grinding wheel is trued while grinding, and the in-feed head being graduated to one-thousandth of an inch, allows the attachment to be fed in by the same amount as the wheel diameter is reduced by wear and dressing. The diamond holder is graduated in degrees corresponding with the incline of the spindle and is set accordingly. If the spindle for a particular thread is set, say, at 5 deg., to correspond with a thread with a helix of that angle, the diamond holder is set at 5 deg. in the opposite direction, thus bringing the diamond holder perfectly horizontal and parallel with the work centres.

The two diamonds are arranged so that one feeds in after the other, thus preventing, should one become dull, the wheel being forced into the other. The diamonds are set at an angle of 10 deg. to their line of traverse, and after slight wear can be given a partial turn to bring a new point to bear on the wheel. The diamonds are traversed out at the necessary angle across the wheel, to give the V face, by turning the double-ended handle (Fig. 3). A stop is provided for limiting the return traverse, and this can be utilised for obtaining the amount of flat required at the bottom of the thread angle. By this the same amount of flat can be insured, regardless of re-dressing, and without subsequent re-gauging. The trueing head enables larger wheels than formerly to be utilised, an 8-in. wheel being practicable, and the grinding time is thus greatly reduced.

Fig. 2 illustrates the trueing device attached to a surface grinder using a 10-in. wheel, at work on grinding thread chasers held on a magnetic chuck. The illustration, Fig. 4, shows the holder or adapter used in this connection, the large ring being fixed over the spindle front bearing cover, and the trueing device being screwed on to the threaded boss shown to the right. An even depth of cut is maintained in this case by lowering the grinder head an amount corresponding with the reduction of the wheel at each trueing, as shown by the in-feed graduated scale.

PERSONAL.—Sir Montagu Sharpe, K.C., D.L., who has received the honour of knighthood, has been chairman of Messrs. John Birch and Co., Limited, export engineers, 2, London Wall-buildings, London, E.C., for a period of nearly 30 years.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—As a result of the experience obtained by keeping the library open every evening and Saturday afternoons during the last few weeks, the Council of the Institution of Electrical Engineers have decided that in future the library will be kept open until 9.30 p.m. on the nights on which are held the ordinary meetings of the Institution, the informal meetings and meetings of the Wireless and Students' Sections.

THE OPTICAL SOCIETY.

AT a meeting of the Optical Society held at the Imperial College on Thursday, January 12, Mr. R. S. Whipple, President, in the chair, three papers were read and discussed.

The first was on "*The Manufacture of Optical Glass*," the author being Dr. C. J. Peddle. The history of the manufacture of optical glass, he said, could be divided into four epochs, Guinand's discovery of the stirring process in 1796, the work of Abbe and Schott about 1882, and the development in England during the Great War, being the outstanding features in this history. The method of manufacture, which was described in detail, was practically the same at the present time as in Guinand's day, any improvement being one of degree rather than of kind. For successful production of the various types the effects of composition upon density, refractive index, melting properties, durability, freedom from colour, and devitrification tendencies, had to be studied upon a small scale, and the results translated into terms suitable for works practice. Results were given of systematic investigations to determine the relation between composition and these various properties.

The second paper was on "*The Barr and Stroud 100-ft. Self-contained Base Rangefinder*," and was by Dr. James W. French. Depression, two-position, and, more recently, self-contained types of rangefinder, had been employed for coast defence purposes. The first two types were subject to several disadvantages which had led to the introduction of the 100-ft. base self-contained instrument. The rangefinder had a new type of triple field. It was carried upon a mounting comprising two trucks running upon a roller path of 50 ft. diameter, the trucks being connected by a rigid horizontal framework. Upon the trucks were carried cantilevers from the ends of which were suspended cradles having special bearings, within which the rangefinder rests. Training was done by power or by hand. During extensive tests the uncertainty of observtion at a range of 31,000 metres did not exceed 20 metres.

The third paper was on "*The Optical Three Apertures Problem*," and was by T. Smith, F.Inst.P. In such an instrument as a submarine periscope, he said, where broad beams of light have to be transmitted down a long tube from a wide field the relation between the length and diameter of the tube and the number of lenses had to be considered. Various types of construction were indicated together with the relative advantages offered by them.

EXTENSION OF SHIPPING FACILITIES WITH THE FAR EAST.—The Transatlantic Steamship Company, Gothenburg (Sweden), are extending their South American service to China and Japan. Their vessels, which load at northern Continental ports for the Mexican Gulf and South American ports, instead of returning, are now loading at the latter ports for China and Japan, and will then proceed to the Dutch East Indies to load cargo for Europe.

INDUSTRIAL PROPERTY IN BELGIUM.—A dispatch has been received from the Belgian Ambassador stating that by a Royal Decree, dated November 4, and published in the *Moniteur Belge*, Article 13 of the Belgian Law of October 11, 1919, which provides that the period of the war shall not be taken in account in reckoning the term of the duration of patents, has been applied to nationals of the United Kingdom. A copy of the dispatch may be seen in the Patent Office Library, 25, Southampton-buildings, London, W.C. 2.

NARROW-GAUGE LOCOMOTIVES FOR ARGENTINA.—A telegram has been received in the Department of Overseas Trade from the Commercial Secretary to H.M. Legation at Buenos Ayres, to the effect that the Argentine State Railways are calling for tenders to be presented by February 22, for 50 narrow-gauge locomotives, the gauge being 750 mm. The telegram adds that specifications (which will presumably be in Spanish) are on their way, and these, when received, will be available for inspection at the department on application to Mr. Dempster, Engineering Section. This advance information is given so that works may be able to instruct their agents in the Argentine to get into touch with the authorities. Communications on the matter should be addressed as follows:—Dirección General, Ferrocarriles del Estado, Buenos Ayres, Argentine.

WATER SUPPLY TO STEAM WAGONS AND ROAD ENGINES.—Following upon the reading of a paper by Colonel Davidson, C.M.G., M.Inst.C.E., waterworks engineer, of Liverpool, on the above subject at the Public Works Congress on November 24 last, a conjoint committee of representatives of the British Waterworks Association and the Association of Motor Users and Manufacturers decided to obtain designs by public invitation for a lock mechanism to be applied to a street service box from which a water supply could be obtained. The lock mechanism would prevent supplies being drawn by unauthorised parties and would be operated by a special key and token which would be furnished to subscribers. In one suggested form of the box a pivoted shutter would cover a circular orifice through which the suction hose from the wagon would be inserted. The insertion of the key would release the shutter, but it could not be swung until the insertion of the token, which in turn could not be used without the key. A premium not exceeding 25 guineas is offered for the best design, which must be submitted before February 14 next. Full particulars may be obtained from the Secretary of the British Waterworks Association, New River Head, 173, Rosebery-avenue, London, E.C. 1.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—A stronger tone is developing in the market for raw and semi-finished materials now that local prices have been brought into comparison with those of Continental competitors. As a matter of fact several brands of Sheffield steel are cheaper than similar steel offered by France and Belgium. A further encouraging feature is the marked increase in the number of inquiries. According to advices which have reached local steel works, this is due to the fact that German makers are largely booked up, and that manufacturers in France and Belgium have little opportunity of increasing their output. There is an improved demand for scrap resulting from greater activity at the steel furnaces, but merchants are asking premiums on listed rates so as to cover themselves against heavy losses during the past six months. Movement in the market for ferro-alloys is still very slow. Makers of heavy steel are taking an interest in forward quotations for ferro-silicon. There is also a minor demand from the few firms making rustless iron for carbon ferro-chrome. The future of the armament-making departments will not be determined until the full effect of the Washington Conference is known, but it is significant that expert staffs are being greatly reduced. It is hoped to utilise some of the heavy plant in connection with electric power, traction and transportation schemes. Orders for renewals are filtering through from home railways, and are proving very useful in enabling rolling mills to maintain part-time working. Business shows more activity in the section devoted to automobile engineering. Trade in gardening tools is retarded by the belief that cheaper rates will ensue. Steelmakers are taking action to induce the Customs authorities to require the country of origin to be shown on imported goods bearing the names of English traders intended for free distribution on advertising account. Definite information has been received that the plans for Sheffield's new automatic telephone exchange have been completed. Tenders are to be invited at once.

South Yorkshire Coal Trade.—Weakness in secondary grades of fuel is attributed to the further dumping on the house coal section of a big tonnage of manufacturing brands left over from the Christmas stoppage. The demand for best house coal, in contrast, is exceptionally brisk. Collieries are well booked forward, and have no difficulty in maintaining full rates. A slight improvement is reported in steam coal for home consumption, but on export account South Yorkshire feels the effect of severe competition from those areas in the North and South Wales which enjoy the benefit of lower transport rates to the coast. Inland works are drawing on stocks of gas fuels, and will soon be in the market again for renewals. Selling pressure is noticeable in smalls. There is little movement in coke. Quotations:—Best branch handpicked, 39*s.* to 40*s.*; Barnsley best Silkstone, 38*s.* to 40*s.*; Derbyshire best brights, 35*s.* to 36*s.*; Derbyshire best house coal, 34*s.* 6*d.* to 35*s.*; Derbyshire best large nuts, 30*s.* to 32*s.*; Derbyshire small nuts, 27*s.* to 28*s.*; Yorkshire hards, 29*s.* to 30*s.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 17*s.* to 18*s.*; nutty slacks, 15*s.* to 16*s.*; smalls, 5*s.* to 10*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—As was anticipated, last week's cut in Cleveland pig iron prices has been followed by a fair number of sales. Inquiries both on home and foreign account have become numerous, and have already resulted in quite substantial sales to home customers, while a few moderate parcels have been disposed of to Continental buyers. Producers agreed-on minimum prices for home use, and for shipment abroad, are: No. 1 Cleveland, 95*s.*; No. 3 G.M.B., 90*s.*; No. 4 foundry, 87*s.* 6*d.*; and No. 4 forge, 82*s.* 6*d.* There is no restriction of price as regards mottled and white iron. These qualities are very plentiful and makers are anxious to receive offers for them. Producers put the price of both descriptions at 80*s.*, but would doubtless readily book orders at a good deal below that figure.

Hematite.—There is considerable demand for East Coast hematite, but with keen competition for the orders in the market-makers, who in this branch are not hampered by price restrictions, are undercutting each other. The general market quotation f.o.t. and f.o.b. for Nos. 1, 2 and 3 East Coast brands is 95*s.* No. 1 hematite is half-a-crown above mixed Nos.

Output of Pig Iron Increasing.—Production of pig iron is steadily but slowly increasing. Messrs. Bolckow, Vaughan and Co., Limited, have blown in a furnace on ferro-manganese; the Skinningrove Iron Company, Limited, are re-kindling two furnaces to turn out Cleveland pig iron; and an additional furnace is going in at the Thornaby Ironworks of Messrs. Whitwell and Co., Limited. This increases the number of blast furnaces in operation on the North East Coast to 28.

Foreign Ore.—There is more inquiry for foreign ore, but as yet business has not expanded to any extent. Best rubio is in the neighbourhood of 26*s.* 6*d.* c.i.f., but consumers appear to be more inclined to negotiate for Mediterranean ores because of their relative cheapness.

Coke.—Coke keeps quiet. Values tend downward, but the prices named are still more than local users are disposed to pay. Average blastfurnace Durhams are quoted 26*s.* 6*d.* to 27*s.* delivered.

Manufactured Iron and Steel.—Little new can be reported of the various branches of the finished iron and steel industries. Manufacturers generally are badly

off for work. Customers are apparently waiting for a further drop in prices which are already altogether unremunerative to producers. Producers are prepared to cut quotations for foreign work, but adhere to the following for home purposes: Common iron bars, 12*l.* 10*s.*; iron rivets, 14*l.* 10*s.*; soft steel billets, 7*l.* 10*s.*; medium steel billets, 9*l.*; hard steel billets, 9*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.*; black sheets, 13*l.* 10*s.*; and corrugated galvanised sheets, 17*l.*

Shipbuilding.—The slump in shipbuilding is general on Teesside, and unless orders are secured nearly all the yards on the Tees will be idle a few months hence. Messrs. Smith's Dock shipyard at South Bank have practically got through their contracts, and the firm have little to keep that portion of their undertakings occupied. Their ship repair department, however, whilst by no means busy, is fairly well placed, and the immediate outlook may be described as satisfactory.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Work is gradually being resumed in the various establishments throughout the country, but the demand for steel material shows little sign of expansion. A number of the rolling mills have been restarted now, but the orders which have accumulated since the closing down at the end of the year are not very satisfactory and employment generally is of a hand-to-mouth character. For almost no class of steel is there any pressing inquiry as yet, but better trade is looked for as the year advances. The re-starting of the works of the Lanarkshire Steel Company at Motherwell within the next week or two is looked upon as a hopeful sign, and this week a gang of labourers commenced to put things in order as the works have been idle for over a year. In the black sheet branch of the industry there is little improvement to record. Prices all round have an easier tendency although there is practically no change over the week. The export trade is sluggish and is very slow to open out, but freights are more encouraging. Prices may be taken as under, but in the case of ship plates and sections more favourable quotations are obtainable on account of the competition prevailing. Boiler plates, 14*l.* per ton; ship plates, 10*l.* 10*s.* per ton; sections, 10*l.* per ton, all net delivered Glasgow stations.

Malleable Iron Trade.—There has been little change in the West of Scotland malleable iron trade this week, and only a proportion of the works are now manufacturing bar iron. Orders are few and far between, and only a limited number of inquiries are in the market. The immediate outlook is a trifle clouded, and managements, although hopeful for the near future, have some difficulty in seeing very far ahead at the present time. No change has been made in prices, and the basis quotation for "crown" bars is 12*l.* 10*s.* per ton delivered Glasgow, but export lots receive very favourable consideration and makers are prepared to cut freely in order to secure the business.

Scottish Pig-Iron Trade.—Although no actual improvement has taken place in the Scottish pig-iron trade during the past week rather a better tone is noticeable, and producers anticipate more business before long. Prices have eased all round about 7*s.* 6*d.* per ton, and that reduction should now help materially to a better demand for the home product and to fewer orders being passed for foreign makers. Local business is still slow, but as improvement takes place more furnaces will be rekindled. Export orders are very poor. Foundry iron No. 1 is round 5*l.* 12*s.* 6*d.* per ton, and No. 3 is called 5*l.* 7*s.* 6*d.* per ton, while Scottish hematite is 5*l.* 15*s.* per ton, delivery as usual; but whenever actual business is in sight these quotations are generally subject to decided concessions on the part of sellers.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Though the work of coal shipping at the docks continues active, business on the market is slow and buyers are apparently content to follow a hand-to-mouth policy by placing their orders from week to week or month to month. It is true that several inquiries are in circulation for delivery over the next few months, but generally they are for small quantities, and sellers in the majority of cases do not care to quote forward in view of the low level of prices and comparative high cost of production. The inadequacy of loading accommodation at the docks to deal with the quantity of coal sent for shipment is also handicapping sellers in their fight to maintain prices, for, with slow loading, trucks are unduly delayed and the result is that sellers in many cases are compelled to cut their prices to secure a quick release of wagons. Buyers are not slow to take advantage of the position, and where possible secure part cargoes before vessels go under berth, and obtain the remainder when loading is in progress with the object of securing the fullest discounts possible. Large coals of all descriptions are especially irregular. Best Admiralty large ranges from 24*s.* 6*d.* to 25*s.*; seconds, 24*s.* to 24*s.* 6*d.*; the leading Monmouthshires, 22*s.* 6*d.* to 23*s.* 6*d.*; best dry, 24*s.* to 24*s.* 6*d.*; and ordinary dry, 23*s.* to 23*s.* 6*d.* Concessions of 3*d.* to 6*d.* are obtainable for spot loading. The better grade steam smalls continue scarce and firm at 17*s.* to 17*s.* 6*d.*, taken in conjunction with large, while cargo smalls are from 13*s.* to 15*s.*, and dry smalls from 11*s.* to 14*s.* Sized coals are in demand and with the make limited prices are firm with dry nuts from 35*s.* to 37*s.* 6*d.*; steam nuts, 27*s.* 6*d.* to 30*s.*; dry beans, 23*s.* to 24*s.*; and steam beans, 24*s.* to 25*s.* The reason why dry nuts are so high is that they are being used as a substitute for anthracite nuts which are round 72*s.* 6*d.* The dock companies have made a further modification in their non-statutory charges. The concessions are, however, not considered sufficient by the general committee of traders dealing with the matter, and they have informed the Dock-owners' Association that unless still further reductions are made they will be compelled to take what steps they consider necessary to secure a further lowering of charges. They threaten to take action as to testing the legality of the increased non-statutory charges, but hint that they desire a friendly solution of the matter and have asked the Dockowners' Association for another meeting.

Iron and Steel Trades.—Owing to the absence of demand the price of Welsh tinplates continues to recede. Stocks are accumulating, and it is feared that unless there is a speedy change in the position some of the mills which have been re-started will have to close down again. At present standard boxes range from 19*s.* 9*d.* to 20*s.* f.o.t. During the week a section of the Japanese Commercial Mission paid a visit to the South Wales ports and made a tour of the various docks and works. At Swansea they were privileged to see Japanese orders for tinplates, &c., being executed at the mills. Welsh steel bars have been reduced 7*s.* 6*d.* per ton to 7*l.* 7*s.* 6*d.* in consequence of the lowering of the price of pig-iron. Billets are also easier at 7*l.* 10*s.*

COMPANY REGISTRATIONS IN 1921.—Messrs. Jordan and Sons, Limited, company registration agents, Chancery-lane, W.C.2, have sent us a copy of a table which they have compiled, enumerating the public and private company registrations at Somerset House, from January 1 to December 31, 1921. From this we take the following figures: Electricity and gas, 115 companies with 1,879,800*l.*; engineers, 351 and 2,948,375*l.*; iron, brass, &c., 397 and 5,927,422*l.*; motors, 288 and 2,390,084*l.*; railways, 8 and 645,500*l.*; shipping, 208 and 3,183,250*l.*; textiles, 394 and 7,473,202*l.* The largest number were food companies, 454 in number, for a total capital of 9,710,085*l.* In 1921 the total number of companies registered was 6,395 for a total capital of 99,034,325*l.*, as against 10,065 companies and 568,894,382*l.* for the preceding year.

DIESEL ENGINE USERS' ASSOCIATION.—At the last meeting of the Diesel Engine Users' Association, Mr. C. O. Milton, Electrical Engineer to the Borough of Maidenhead, was re-elected President for a second year, and Mr. Percy Still was re-elected Honorary Secretary. Messrs. H. S. Whiteley and W. E. Brandreth were elected members of the General Committee in place of the two members retiring at the end of their term of office. The members forming the Standard Committee on Insurance against Breakdown, which deals with any questions arising in connection with the standard policy of insurance against breakdown adopted by the Association, were re-elected for a further term of office. The hon. secretary made his annual statement which reported a further substantial increase in the membership of the Association during the year. By the courtesy of the Institution of Electrical Engineers, the meetings of the Association are now again being held in that Institution's building. In view of the tendency in the design of pure Diesel engines to approach more nearly in some respects the lines of semi-Diesel engine design, and vice-versa, the President, in the course of one of the discussions, had made the suggestion that it might possibly become advisable in the future to alter the name of the Association by adopting some such name as "The Heavy Oil Engine Users' Association."

LLOYD'S REGISTER OF SHIPPING.—The General Committee of Lloyd's Register of Shipping at their meeting on the 12th inst. elected Mr. J. Herbert Scrutton as Chairman, Sir Thomas J. Storey, K.B.E., as Deputy-Chairman and Treasurer, and Captain H. B. Hooper, R.I.M., as Chairman of the Sub-Committees of Classification of the Society. Mr. Scrutton succeeds Sir John H. Luscombe as Chairman, the latter gentleman having expressed a desire to retire from office at the end of 1921. Mr. Scrutton, who is a partner in the old-established firm of Messrs. Scrutton, Sons and Co., which was founded by his grandfather, was Chairman of the General Shipowners' Society for the year 1905–6, when he first took his seat on the Committee of Lloyd's Register, on which he has since served continuously. It is a remarkable fact that during the 88 years since the Society was re-constituted in 1834 there have only been seven chairman, among whom may be mentioned the following notable men: Mr. Thomas Chapman, F.R.S., F.S.A. (1835 to 1881), Sir John Glover (1899 to 1907), and Sir Thomas L. Devitt, Bart. (1909 to 1920). Sir Thomas J. Storey, K.B.E., who has been Chairman of the Sub-Committees of Classification since 1917, has been elected to succeed Mr. Scrutton as Deputy-Chairman and Treasurer. Captain H. B. Hooper, R.I.M., has been elected to succeed Sir Thomas Storey as Chairman of the Sub-Committees of Classification. Among other recent changes on the committee, it will be of interest to mention that Sir Alexander Kennedy, of the Fairfield Shipbuilding and Engineering Company, and the Northumberland Shipbuilding Company, and Mr. James Brown, C.B.E., of Scott's Shipbuilding and Engineering Company, have been elected to the General Committee in place of Sir Alexander Gracie, K.B.E., M.V.O., and Mr. James Denny, neither of whom sought re-election at the end of their term of office in December, 1921.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 20, at 8 p.m., at Caxton Hall. Lecturette, "Geology in its Relation to Engineering."

THE INSTITUTION OF CIVIL ENGINEERS, YORKSHIRE ASSOCIATION.—Monday, January 23, at 7.30 p.m. Paper on "Re-inforced Concrete Water Tower at York," by Mr. W. H. Humphreys and Mr. J. Gilchrist.

THE BRADFORD ENGINEERING SOCIETY.—Monday, January 23, at 7.30 p.m. Lecture in the Hall of the Bradford Technical College on "The Protection of Industrial Invention," by Mr. J. V. Armstrong.

THE ROYAL SOCIETY OF ARTS.—Monday, January 23, at 8 p.m.: Cantor Lecture, "Inks." By Mr. C. Ainsworth Mitchell, M.A., F.I.C. (Lecture I). Wednesday, January 25, at 8 p.m.: Ordinary meeting, "Photo-Sculpture." By Mr. Howard Maurice Edmunds. Mr. Alan A. Campbell Swinton, F.R.S., Chairman of the Council, will preside. Friday, January 27, at 4.30 p.m.: Indian Section, "The Timbers of India and Burma." By Mr. Alexander L. Howard. The Right Hon. E. S. Montagu, M.P., Secretary of State for India, will preside.

THE NEWCOMEN SOCIETY.—Tuesday, January 24, at 5 p.m., at Caxton Hall, Westminster. Paper by Mr. T. E. Jones, M.A., LL.D., on the "Mechanics of Engineering from the Time of Aristotle to that of Archimedes."

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, January 24, at 6 p.m. Papers to be further discussed: "Control of Trains, in Relation to Increased Weight and Speed combined with Reduced Headway," by Mr. Alan Wood Rendell, M.Inst.C.E.; and "Trials in Connection with the Application of the Vacuum Brake for Long Freight Trains," by Sir Henry Fowler, K.B.E., and Mr. Herbert Nigel Gresley, C.B.E., M.Inst.C.E.

THE INSTITUTION OF CIVIL ENGINEERS.—Wednesday, January 25, at 6 p.m. Students' meeting. The second lecture on "The Economic Aspects of Various Methods of Power-Transmission," by Mr. E. W. Monkhouse, M.A., M.Inst.C.E. Mr. Basil Mott, C.B., Vice-President, will occupy the chair. Students' visit, Saturday, January 28, at 10 a.m., to the Central Telegraph Office of the General Post Office.

THE WEST BROMWICH ENGINEERING SOCIETY.—Wednesday, January 25, at 7.30 p.m., at the Technical School. Paper on "Small Lighting Sets," by Mr. W. Wilson, B.E., M.Sc., A.M.I.E.E. (Research Department, G.E.C.). Demonstrations with a complete unit and lantern illustrations.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, January 25, at 8 p.m., at the Royal Institution, Colquitt Street, Liverpool. Paper on "The Removal and Replacement of New Brighton Landing Stage Bridges by Floating Crane," by Mr. H. A. Whitaker, M.Eng. (Liverpool).

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Thursday, January 26, 1922, at 7.15 p.m., at Caxton Hall. Paper by Mr. Cecil J. Allen, associate, on "Notes on the Influence of Design on Express Locomotive Performance."

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, January 27, at 9 p.m. Discourse by Viscount Burnham, J.P., on "Journalism." Afternoon lectures, at 3 p.m.: Tuesday, January 24, Mr. F. H. A. Marshall, Sc.D., F.R.S., on "Physiology as Applied to Agriculture" (Lecture II); Thursday, January 26, Mr. Seton Gordon, F.Z.S., on (II) "Sea Birds and Seals"; Saturday, January 28, Mr. Charles Macpherson, Mus.Doc., Prof. R.A.M., St. Paul's Cathedral, Pres. Roy. Coll. of Organists, on "The Evolution of Organ Music" (with musical illustrations) (Lecture II).

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—Saturday, January 28, at 2.15 p.m., in the Danum Hotel, Doncaster. Paper, "The Ignition of Firedamp," by Professor R. V. Wheeler, D.Sc. The following paper will be open for discussion: "The Metering of Large Volumes of Air and Gas by means of the Venturi Tube," by Mr. J. L. Hodgson.

AERIAL NAVIGATION LIGHTS.—At a joint meeting of the Royal Aeronautical Society and the Illuminating Engineering Society to be held on Tuesday, the 31st inst., at the Royal Society of Arts, John Street, Adelphi, W.C. 2, Lieut.-Colonel L. F. Blandy will read a paper entitled "The Use of Light as an Aid to Aerial Navigation." The chair will be taken by Major-General Sir Frederick Sykes, Controller-General of Civil Aviation, at 8 p.m.

UNIVERSITY OF LONDON, UNIVERSITY COLLEGE.—A course of lectures on "Waterways, Harbours and Docks" will be delivered by Dr. Brysson Cunningham, on Tuesdays and Fridays, at 4 p.m., beginning January 24. The course is open to both members and non-members of the university. The fee is 3*l.* 3*s.* Applications for tickets of admission should be made to Dr. Walter W. Seton, Secretary, University College, London, Gower-street, W.C. 1.

THE PORT OF SWANSEA.—Very complete information on the port of Swansea is contained in the handbook for the current year, compiled by Mr. H. N. Appleby, and recently issued by the Swansea Harbour Trust, General Manager's Office, Swansea. The information comprises statistical figures, particulars concerning the docks and their equipment, tides, lines of steamers trading between Swansea and ports throughout the world, harbour and dock rates, &c.

WHEEL-TRUEING ATTACHMENT FOR SCREW-THREAD GRINDING.

CONSTRUCTED BY THE PRECISION AND THREAD GRINDER MANUFACTURING COMPANY, PHILADELPHIA, PA., U.S.A.

(*For Description, see page* 76.)

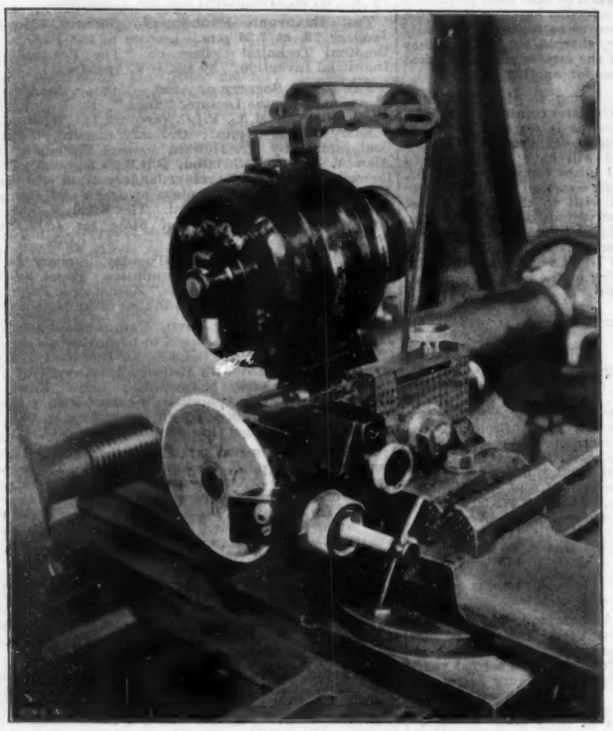


FIG. 1. THE ATTACHMENT USED WITH A MULTI-GRADUATED PRECISION THREAD-GRINDER.

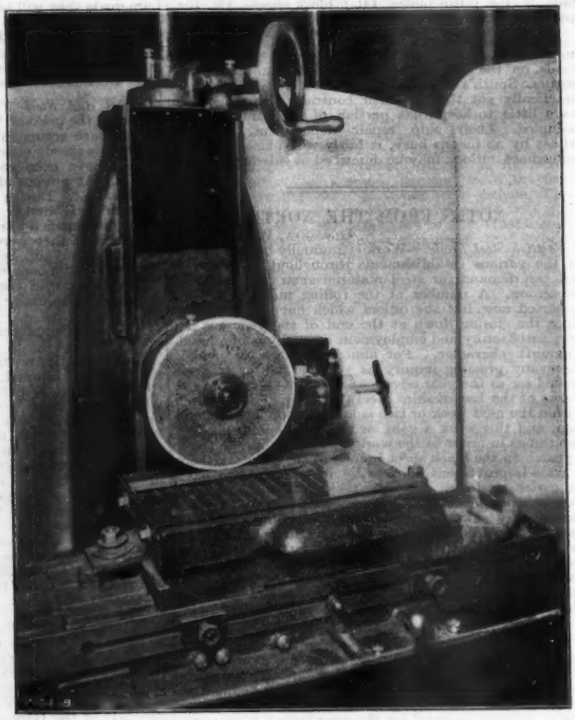


FIG. 2. THE ATTACHMENT USED ON A SURFACE-GRINDER FOR GRINDING CHASERS.

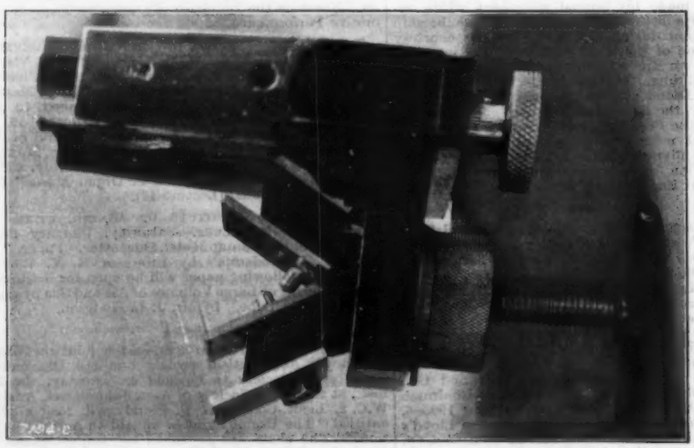


FIG. 3. THE TRUEING ATTACHMENT.

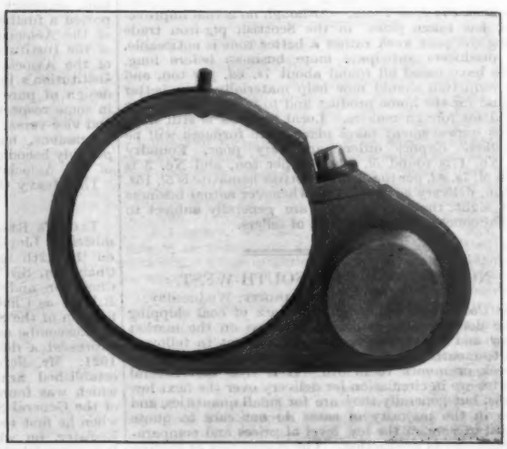


FIG. 4. ADAPTER FOR USE ON SURFACE-GRINDER.

SWISS GLIDER COMPETITION.—The secretary of the Royal Aeronautical Society announces that he has received, through the Controller of Information of the Air Ministry, particulars of a soaring flight competition to be held at Gstaad, in the Bernese Oberland, by the Suisse-Centrale section of the Swiss Aero Club, from March 8 to 15 next. A translation of the regulations can be inspected at the society's offices, 7, Albemarle-street, W. 1, and intending participants are asked to communicate with the secretary. In connection with the competition a course of instruction in practical soaring is being arranged at Gstaad from February 15 to March 15.

MOTOR LIFEBOAT FOR CHILE.—We recently had an opportunity of inspecting a motor lifeboat constructed by Messrs. John I. Thornycroft and Co., Limited, 10, Grosvenor-place, London, S.W. 1, to the order of the Chilian Government. The boat, which has a length of 35 ft., a beam of 8 ft. 6 in., and a draught of 3 ft. 3 in. is similar in design to those employed by the Royal National Lifeboat Institution, and is of the self-righting type with the bow and stern portions built high to accommodate the air tanks. The centre portion, which is kept low, has a self-draining well with the usual non-return valves and pipes leading through the bottom skin of the boat. Rowing thwarts are fitted, and sails are carried in accordance with usual lifeboat practice, but the boat is normally propelled by a Thornycroft M-4 type four-cylinder petrol engine developing 36 b.h.p. and driving a screw propeller working in a tunnel. The latter is of larger dimensions than usual, since, in order to secure higher propulsive efficiency and better manœuvring power, the propeller is driven through the builders' combined reducing and reversing gear at 350 r.p.m., while the engine runs at 1,000 r.p.m. The engine and gear are enclosed in a water-tight and air-tight casing, the air supply for the engine being admitted through a ball-valve fitting arranged so that the air is automatically cut off in the event of the boat capsizing. The exhaust pipes are arranged so that the gases can escape from either, or both, sides of the boat, according to the angle of heel, and ball valves are fitted to prevent the entrance of water when either of the outlets is submerged. All controls, and the starting handle, are arranged outside the engine casing and a mercury switch is fitted in the ignition system to break the connection if the boat heels to an angle of 45 deg. or over. The boat is steered by handwheel or tiller and speeds of 7·89 knots forward and about 7 knots astern were attained on trial.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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ENGINEERING.

FRIDAY, JANUARY 20, 1922.

A NEW PROBLEM IN TUNNEL VENTILATION.

THE development of underground urban traffic has frequently given rise to new problems in ventilation. In the case of ordinary main line tunnels natural ventilation has, with few exceptions, proved sufficient, and serious trouble has only been met with in certain long tunnels through Swiss and Italian mountains. Until these were artificially ventilated, there were occasions on which engine crews were found unconscious when the train finally emerged, and when, as sometimes happened, the train was held up in the tunnel for some time, the passengers were also affected. Travellers on the London underground railways when these were operated by steam have vivid recollections of the state of the air at Gower Street station, but we believe that, though highly unpleasant, the condition of affairs was not seriously injurious to health. The tunnels on these lines were not far below the surface and natural ventilation was fairly effective. Moreover, the intensity of the traffic even during rush hours was relatively light as compared with modern standards.

With the advent of the tubes conditions changed greatly. At the outset it was thought that in view of the abolition of the steam locomotive natural ventilation would prove adequate in spite of the great increase of the depth below ground level and of the diminution of the tunnel cross section. Experience falsified this hope as the air soon became very foul and the pollution was of a more repellent character than that met with on the steam-operated underground lines. It is common knowledge that the companies concerned have tackled the problem thus presented to them with great enterprise and ability so that now not merely do they force into their tunnels fresh air but ozonised air, and to-day the state of the tubes gives little or no ground for complaint.

A new variant of the problem of tunnel ventilation has arisen in New York in connection with a tunnel for vehicular traffic which is to be constructed under the Hudson River. This tunnel will have a total length of 8,300 ft. between portals, and will consist of two cast-iron tubes 29 ft. in diameter lined with concrete and laid side by side across the river. Each tube will provide a roadway 20 ft. wide, and a footpath 2 ft. wide, and each will be traversed by traffic moving in one direction only. The intensity of this traffic is estimated at 1,900 vehicles per hour, of which, as matters stand, rather more than one-half will certainly be motor driven, and this proportion will undoubtedly increase largely with the lapse of years. For the sake of comparison it may be mentioned that a count taken in 1920 showed that rather less than 100 motor vehicles per hour traversed the Blackwall tunnel, which is 6,200 ft. in length between portals, the under river length between shafts being 1,221 ft. At the Hudson the distance between shafts is to be 3,375 ft. or nearly three times as great, whilst the amount of motor traffic expected is about 1,100 vehicles per hour in addition to horse-hauled traffic. The conditions are accordingly widely different from any hitherto dealt with.

The new factor is the high density of the motor traffic. The exhaust gases from petrol motors, as was proved here in the early days of the automobile, commonly contain a considerable percentage of carbon-monoxide. The effects of this gas on the human system were studied here many years ago by Dr. J. S. Haldane, in connection with an inquiry into the state of the air on the Metropolitan Railway when steam traction was employed. Where the exposure to the gas is prolonged over several hours, Dr. Haldane has concluded that the contamination should not exceed 2 parts in 10,000, but for exposures of less than an hour no harm would be done if the amount of carbon-monoxide present did not exceed 5 parts in 10,000. It is important to note that the combination of carbon-monoxide with the hemoglobin of the blood is a reversible one, so that it is gradually eliminated from the system if a patient half poisoned with it is removed into the fresh air.

In view of the very heavy traffic which the new tunnel is to accommodate it was thought desirable to investigate the matter afresh, since the power required to reduce the pollution to 5 parts in 10,000 would be only 22 per cent. of that required to reduce it to 3 parts in 10,000.

The biological experiments were carried out under the direction of Dr. Yandell Henderson at Yale and the experiments upon the amount of CO to be expected in the exhaust of petrol engines at the Pittsburgh experimental station under the direction of Mr. A. C. Fieldner. The reports of these gentlemen have now been published by the Tunnel Commission and we are indebted to Mr. C. H. S. Tupholme for a copy. The biological experiments yielded results in close accord with those obtained by Dr. Haldane. The typical symptom of the poisoning was found to be headache. With an hour's exposure to air containing 4 parts of CO in 10,000 there was no headache, with 6 parts it was slight, whilst with 8 parts per 10,000 it lasted for several hours after the removal of the "patient" from the experimental chamber. It was concluded that the ventilation of the tunnel would be satisfactory if the pollution by CO was below 4 parts in 10,000.

The experiments at Pittsburgh were made on 101 motors of different descriptions, ranging from light pleasure cars up to lorries carrying 5 tons or more. All conditions of working were covered in the tests, from the engines running idle, up to exerting their maximum power on heavy gradients.

The controlling factor in the production of carbon-monoxide was found to be the carburetter adjustment. If set so as to obtain maximum economy, the amount of carbon-monoxide was little or nothing, but this desideratum is accompanied by the drawbacks of a lack of flexibility and by a large reduction in the maximum power developed. Generally it appeared that carburetters are adjusted to give maximum power. For maximum thermal efficiency the mixture entering the engine should consist of about 16 lb. of air to one of petrol, but the maximum power is obtained with but 12 lb. or 13 lb. of air. With still richer mixtures there is little falling off in power, which with 9 lb. of air to one of gasoline is still only 10 per cent. less

than the maximum. At maximum thermal efficiency the power is about 6 per cent. less than the maximum, and as already stated the flexibility is greatly diminished.

With the usual adjustment of the carburetter, combustion in the cylinder is far from complete. As an average figure, about 6·7 per cent. of carbon-monoxide may be expected in the exhaust gases, which is equivalent to a loss of about 30 per cent. of the total heat of combustion of the petrol. This is a normal figure, but extremes were met with in both directions. In one case the carburetter had been adjusted so that there was none of the monoxide present in the exhaust, whilst in another instance as much as 13·2 per cent. was found. Air pollution depends, of course, not merely on the proportion of the monoxide present but also on the total volume of the exhaust. With heavy lorries having a capacity of 5 tons or more the total volume of CO_2 liberated whilst climbing a gradient of 3 per cent. at 10 miles per hour amounted to 199·3 cub. ft. per minute. Running down the same gradient at 6 miles per hour the amount was 48·1 cub. ft. per minute. On the level at 10 miles per hour, the discharge of CO was 167·5 cub. ft. per minute, which was diminished to 124·9 cub. ft. per minute when the speed was reduced to 6 miles per hour. With motor lorries having a capacity of from 1½ tons to 3 tons the maximum output of CO was 149·6 cub. ft. per minute, and the minimum 24·3 cub. ft. With five-seater passenger cars the corresponding figures were 77·0 cub. ft. and 28·8 cub. ft. per minute respectively. The seven passenger car tests gave a maximum discharge of 144 cub. ft. of CO per minute and a minimum of 41·8 cub. ft. per minute. On the basis of these tests it was decided to provide for completely changing the air in the tunnel forty times per hour, electrically-driven fans being utilised for the purpose.

Certain railway tunnels on the Continent have been ventilated by blowing in air at one portal against the advancing train, but such a system would have been wholly inapplicable in the present case, since it would have implied air velocities of from 51 miles to 72 miles per hour. It has accordingly been decided to adopt a distributive method of ventilation. The incoming air duct is to be constituted by the space under the roadway, and the exhaust takes place through a similar space provided at the top of the tube. There will be adjustable openings between these ducts and the traffic space, by means of which great uniformity of ventilation can be secured. In order to determine the size of fan required, the Commission have arranged for an elaborate series of experiments on the resistance of air ways. These are to be carried out at the Engineering Experiment Station of the University of Illinois, and will be in part financed by the Bureau of Mines, in view of the probable value of the results to mining engineers.

The tunnels are to be constructed on the shield system, which is stated to be specially suitable for the conditions met with at the site. The river bottom consists of a thick bed of soft silt overlying rock, but in one place the rock is so near the river bed that the tunnel must pass through it.

THE AUSTRALIAN RAILWAY GAUGE QUESTION.

CABLE advices from Australia point to the fact that, with expenses at their present level and the difficulty of raising money, nothing is likely to be done in the near future in regard to the provision of a uniform railway gauge for the country. This problem has latterly resolved itself largely into one of finance. Formerly it was complicated by the fact that of the two important gauges neither had sufficient preponderance over the other to remove all question as to which should be considered the standard. We need not now go into details of the controversy which was settled rightly or wrongly when the Commonwealth decided upon the 4 ft. 8½ in. gauge for the Trans-Continental line, which gave that gauge a larger numerical superiority which there was no prospect of wiping out by developments of the 5 ft. 3 in. gauge.

In those days it was realised that financial questions really controlled the situation, and very little actual progress was made, not so much because the cost was regarded as disproportionate to the advantages, though in the sums in which we were then wont to reckon the expenditure involved would have been heavy. The main question was, and we think still will be, when, with the return of normal times, unification becomes again a practicable possibility, the manner in which the cost is to be defrayed, and its apportionment between the different States and the Commonwealth. For instance, the Commonwealth main line and the New South Wales lines are 4 ft. 8½ in., and as it is practically decided that this will be the future standard no expense of conversion will fall on them. On the other hand, it is hardly to be expected that South Australia and Victoria, both of whom have found the 5 ft. 3 in. satisfactory, should bear the whole expense of converting their systems for what is largely a national purpose; if the conversion is to be of advantage to the Continent, either commercially or from the point of view of defence, it is right that both New South Wales and the Commonwealth should contribute material assistance towards the expense. The matter, to our knowledge, has never been carried as far as shaping, in any really practical form, proposals bearing on this aspect, which is, after all, vital to the undertaking.

It is a question whether the present moment would not be opportune for trying to make some progress on these lines. It would be better to formulate a scheme now and have it ready for the hoped-for revival, rather than to wait for the latter and then to waste time with negotiations which might easily drag out till another slump supervened. It is probable that with high railway deficits now staring the States in the face there will be more concern as to how to wipe these out than with regard to what is for the present an academic subject, but it is the statesman's duty to plan ahead, and not just to snatch opportunities as they pass. Some progress made now would reap a good reward when more prosperous times returned.

The latest estimate for cost of conversion, prepared by a Royal Commission which was appointed last year to look into the matter, has recently been published, and the Commission's full report has just reached this country. From this it appears that, as was almost to be expected, the 4 ft. 8½ in. gauge is recommended as the standard, and the cost of converting to this for a system of main trunk lines only is placed at about 18½ millions sterling. If all the 5 ft. 3 in. lines in South Australia and Victoria were converted, the cost it is estimated would be about 21,600,000*l.*; while the conversion of all lines on the Continent, including 3 ft. 6 in., but excepting private systems, would be over 57 millions sterling. It is probable in view of these figures that few people would advocate very strenuously the largest of these expenditures. On the other hand, the part conversion of the 5 ft. 3 in. systems in Victoria and South Australia would so add to the complications of operation that working expenses would be greatly increased. As the main hope of making any railway remunerative in the future rests with a reduction of operating costs, it is probable that it would be better to face the extra capital expenditure involved in converting all such lines, thus arriving at the estimate of 21,600,000*l.* This estimate covers everything which the Commission considers necessary in the way of alterations to existing railways and structures, and allowance (6,873,000*l.*) for new lines involved, with 5,715,000*l.* for adjustment of rolling stock. The largest expenditure would be in Victoria, as the programme involves the conversion of all 5 ft. 3 in. lines. The next heaviest would be in Western Australia in which some 400 miles of 3 ft. 6 in. gauge would have to be converted, the bulk, however, being spent upon deviations, and including a new bridge over the Swan River at Fremantle. In this State the remaining lines would continue as they are as a 3 ft. 6 in. system.

In South Australia, which has a dual system of 5 ft. 3 in. and 3 ft. 6 in., the conversion of the 5 ft. 3 in. only is contemplated. In New South Wales it is proposed that the trunk line to Brisbane should follow the coast, instead of the inland route via Werris Creek and Wallangarra. The coast line at present stops some little way short of the border, and connection would have to be made over this section, and also from the Queensland border on to Brisbane. The conversion of 3 ft. 6 in. lines in Queensland is not included.

The Commission's estimates, which, it may be said, are much less than those prepared by the Commonwealth or individual States, include all expenses which may be debited to conversion, but making, it would seem, every allowance possible for working out old stock discarded from converted lines, on sections which will not be dealt with, and including allowance for conversion of stock as opposed to replacement. Further, where replacement would appear to be unavoidable the cost placed against conversion has been the difference merely of the cost of replacement to 4 ft. 8½ in. standards, as compared with the normal cost of renewal. Whether all the proposals with regard, for instance, to the conversion of locomotives and other stock from 5 ft. 3 in. to 4 ft. 8½ in. gauge are practicable, or come within the estimates allowed, it is impossible to say. The report is not backed by evidence of mechanical engineers on these points, and it must be remembered that work of this class is not only very expensive, but takes a great deal of time to carry out. On the subject of time taken to convert the report is silent. The Commissioners were not asked to estimate on this question, but they do formulate a rough programme according to which they think the work might be undertaken. This naturally proposes first the work on the trunk line, except in the case of Victoria, for which the engineers in that State have suggested a sequence with which the Commission agree. This programme divides the systems radiating from Melbourne into a series of five fans, of which the north-easterly, spreading in the direction of New South Wales, would be tackled first. The second to be undertaken would be the north-westerly section radiating towards the South Australian system. The third section would be that spreading north, while the easterly and westerly sections respectively would be tackled fourth and fifth. In this way the 4 ft. 8½ in. system would spread from New South Wales, while the 5 ft. 3 in. intercourse would be maintained with South Australia as long as possible.

The Commissioners propose that the whole should be in charge of a director-general with a view to co-ordinating work and full advantage being taken of experience, &c. Some organisation under an official of this class would appear to be essential. The undertaking would be difficult in any case, but, with anything in the way of lack of co-operation, the expense and difficulties would be vastly enhanced. We note that the Commission has definitely set its face against any of the make-shift third-rail devices. They rightly point out that such a compromise cannot be a permanent solution, and their adoption would simply add to the ultimate cost. Meanwhile work is indefinitely postponed.

FLASH-POINT TEMPERATURES.

LIKE the ignition points of gas mixtures the flash-points of vaporising liquids, and particularly of petroleum oils, are not regarded as more than empirical constants. The two points are differently defined by different investigators, and their precise values depend upon the test conditions. Practically both the points signify the temperatures at which some gas or vapour inflames in the presence of oxygen. The inflammation is only the visible indication of a combination which had been proceeding at too slow a rate to become visible, and which changes with local conditions. For physicists, therefore, the flash-point is largely a function of the particular apparatus employed, and the flash-points of oils, *i.e.*, complex mixtures, upon which most of the experimental work has been done, cannot rank with other physical constants. But they share this defect with other technical properties, which the engineer takes pains to determine, and the flash-point enjoys legal recognition. The flash-point of a liquid should clearly bear some relation to the boiling-point. According to a paper which Dr. W. R. Ormandy and Mr. C. E. Craven read before the Institution of Petroleum Technologists on Tuesday, the 10th inst., that relation is simple. If the temperatures are expressed in degrees Centigrade on the absolute or Kelvin scale, then

F. P. × C_1 = B. P. × C_2 where the C_1 and C_2 are two constants. The title of the paper was "The Physico-Chemical Significance of Flash-Point Temperatures."

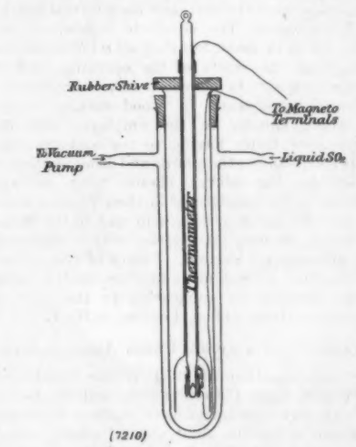
Dr. Ormandy investigating, with the assistance of Messrs. Craven, E. Connolly and Banks, the alcohol solubility of hydrocarbons on behalf of the Distillers Company, Limited, and the Fuel Research Board, observed first that the quotient R of F. P.B. P. had the fairly constant value 0·736 (ranging from 0·72 to 0·78) in the case of a large number of benzene derivatives. They subsequently found that the constancy of R was maintained for kerosenes, motor spirits, alcohols and other compounds. The flash-point apparatus of the Abel and Pensky-Martens types proved unsuitable for this research; these appliances require comparatively large bulks of the material, the surface of the heated liquid is exposed to cooling, and the apparatus cannot be used for testing motor car fuels at the low temperatures. Dr. Ormandy adopted the simple apparatus illustrated in the annexed diagram. Into a test tube, about 10 in. high, is fixed, by means of a rubber stopper, a second test tube, so that the two form a jacket through which liquid sulphur dioxide is drawn by a vacuum pump; by these means the liquid may be cooled to — 70 deg. C. Through a rubber shive, resting loosely on the top of the tubes, a mercury thermometer is suspended, the glass shell of which opens out below into a bell; surrounding the bulb are two rings of copper, insulated from one another, and to these rings two nickel wires, 1 mm. in diameter, are attached, leaving a spark gap of less than 1 mm. These electrodes are joined to a small magneto machine by a strip of tin foil, running along the thermometer, and by a loose wire. Steel ball electrodes, first used, gave erratic results. A strip of dry filter paper is pushed into the bell so as to form an inner lining, not covering the spark gap. The whole is placed in a glass jar.

When a test is to be made at low temperature, about 7 cub. cm. of the liquid are placed in the tube, this amount being sufficient to cover the bell and to saturate the paper. By turning on the sulphur dioxide the liquid is cooled below the (approximately-known) F. P., and the temperature is then allowed to rise at the rate of 1 deg. C. per minute. At each rise of a degree a spark (or several) is passed. In the case of alcohols the flash may be imperceptible. But the explosion makes the thermometer and its shive jump momentarily, the temperature rises by about 2 deg., and more liquid is drawn into the bell, while gas bubbles are forced out. When the explosion was more violent, the temperature rise was too rapid, and the F. P. then observed was too high. When the air was replaced by oxygen, the explosions became unpleasant. Pressure raises the F. P., but only small excess pressures have so far been applied. The number of sparks, 40 sometimes, made no difference in the F. P., and does not raise the temperature of the liquid by more than 2 deg., which is rather surprising. For tests at higher temperatures the apparatus is placed in a water bath; temperatures above 100 deg. C. have not yet been tried.

It was at first intended to plot the F. P. so observed against the true boiling-points, B.P., and that would have been preferable, as Professor Brame, president of the Institution, pointed out. But what is the true B.P. of a complex mixture like kerosene or petrol and alcohol? Dr. Ormandy, adopted, therefore, the "first-drop" temperature, i.e., the temperature read off in the Engler distillation apparatus at the moment when the first drop falls from the condenser end. In his apparatus explosion occurs when something from 0·1 per cent. to 1 per cent. of the liquid has been vaporised. The choice limits the sensitiveness of the apparatus, but it avoids the complication of a fractionation, and the results seem remarkably concordant, as long as the distillation curve is not steep. For pure substances the F.P. value of the drop method was about 1 deg. C. below the true B.P. value, but in the case of tetraline, tetranaphthalene (having a steep curve), the Abel flash was 33 deg. C., and the Ormandy flash 39 deg., corresponding to R values 0·756 and 0·770 respectively.

Whilst steep curves lead to high R values, dissolved gases in the oil favour low values. Now dissolved gases, air and others, are very obstinately retained by hydrocarbons and liquids. Dr. Ormandy spent a week on the purification of hexane and in attempts to prevent reabsorption of gas by the hexane, and the question is whether or not in commercial products those gases should be regarded as constituents of the liquids. There may be errors in the first-drop determination; Dr. Lessing, Dr. Thole and Mr. Harold Moore further referred to this point during the discussion. The first drop is often of a milky turbidity, owing probably to the presence of water in the air, the apparatus (surface films) and the liquid itself, and it might be best not to rely upon the first drop; but in favour of it is its great convenience, and Dr. Ormandy's apparatus admits of easier modifications of volume, pressure, &c., than ordinary flash-point apparatus which are subject to very detailed specifications.

Dr. Ormandy's conclusion is that for any hydrocarbons or mixtures of hydrocarbons, not containing small quantities of volatile impurities, the limiting temperatures at which explosive mixtures are formed in contact with air are constant fractions



of the initial boiling-point. There are, of course, two flash-points, a lower F.P. for the minimum percentage of the substance which will explode with air, and a higher F.P. for the maximum explosive percentage.

The average values of R found were 0·736 for the lower F.P. and 0·800 for the upper flash-point. Both these figures refer to hydrocarbons; there the two curves are parallel straight lines, and it is interesting that the two striking exceptions to the rule, heptane and turpentine, were also found to behave exceptionally in Mr. Ricardo's most recent work on detonation pressures. For alcohols, which show physical peculiarities in many respects, 25 deg. C. should be added to the F.P. observed, to bring the R in line with those of the hydrocarbons. This addition has also to be made in the case of binary mixtures of alcohols with water, ether, and benzene. But even in the cases of mixtures of benzene with toluene and petrol Dr. Ormandy can calculate the flash-point with fair accuracy. From these considerations he further deduced that at the flash-point all hydrocarbons possess approximately the same vapour tension, which, at atmospheric pressure, is 12 mm. of mercury for the lower flash-point and 40 mm. or 50 mm. for the upper flash-point. In the case of the alcohols the vapour pressures at the lower flash-point decreased with increasing molecular weight, from 27·6 mm. for methyl alcohol and 25·6 mm. for ethyl alcohol, to 13·5 mm. for amyl alcohol. Thus, Dr. Ormandy suggested, flash-point determinations might be substituted for the laborious vapour-pressure determinations.

It may be a little early yet for these generalisations, especially as the experiments at pressures of several atmospheres have only been begun. But Dr. Ormandy has certainly done a great deal of new experimental work, and there is something in it for the engineer. A low flash-point means easy starting of the motor, and the figures for the lower and upper flash-point give some idea of the explosive range of a fuel. With the alcohols, and especially with the common ethyl and methyl alcohols, a much greater range of fuel-air ratio seems permissible than with hydrocarbons. For ordinary (ethyl) alcohol the mixture will ignite when from 3·4 per cent. up to 10·6 per cent. of alcohol are present. For the hydrocarbons the range lies between 1·5 per cent. and 4·5 per cent. How the compression in the engine cylinder will affect his data Dr. Ormandy is not yet in a position to say. In the case of an engine cranked by hand it may be taken as a first approximation that the P. V. relationship follows Boyle's law, there being time for a good deal of the heat developed to pass into the cold metal, and on this assumption Dr. Ormandy stated that we are able to calculate at what temperature of carburisation the mixture in an engine with a given compression ratio will cease to ignite. These temperatures, he considered, would be, at pressures of 1, 2, 3, 5 atmospheres, for benzol, — 13, + 5, + 16, + 33 deg. C., and for petrol — 28, — 11, — 1, + 16 deg. C. Thus at a 5 : 1 compression the minimum carburation pressure for benzol would be well above the ordinary atmospheric temperature, whilst for petrol it would only just have reached the latter figure. We know so little about the real nature of ignition that any novel line of research on the subject is welcome.

PATENTS AND PATENT ACTIONS OF 1921.

DURING 1921 more patent applications were lodged in this country than ever before, with the exception of the year 1920, which was the year in which a large influx was recorded due to the removal of the prohibition relating to enemy patent applications and their filing under the Peace Treaty. The total number of applications lodged amounted to 351,163 and there was a notable increase in the rate at which they were filed after the month of August. Before that, specifications were lodged with the usual regularity but the rate was greater towards the end of the year.

During 1921, in actions in the Court, six patents were held valid, five invalid, three applications for extension were refused, and 12 patents were extended.

Among the decided cases an interesting point on "discovery" was settled in which on an inquiry as to damages, in an action for infringement of patents for particular kinds of flux used in welding aluminium, an order was made directing the defendants to state the number of aluminium articles welded by them during the six years before the action, and classifying the articles with the sale price of each class. An application to discharge this order was dismissed.

An electric capstan patent was extended for four years on a patent which had expired before the application for extension. This was a special case due to war circumstances, but should be noted because in another application for extension of a patent that had expired for three years, the application was dismissed.

An application for a patent for a method which consisted in operating a high-compression internal-combustion engine of a certain character with a hydro-carbon fuel with defined characteristics such as cyclo-hexane, was held to be not a manner of manufacture and the Law Officer refused to grant a patent.

He took the same view on an application relating to a certain substance being chemically pure and having a melting point above a temperature specified which he held to be a substance prepared by a chemical process, although the purification employed was effected by the physical process of sublimation. According to the digest of Reported Cases, in an action for infringement of a patent for a chemical process for the manufacture of a colouring matter where the defendants started with a different substance from that used by the plaintiffs, it was held that it was not shown that it was part of the common knowledge at the date of the patent, not only that, as a matter of chemical theory the substance used by the defendants would be formed in the course of the reaction in the plaintiffs' process, but that in the practical application of the process on a commercial scale, the same result would be

obtained by starting with the substance the defendants used. As a result it was held that the defendants had not infringed. This is the important Levenstein case, relating to a black colouring matter directly dyeing cotton.

Not many law cases under the Peace Treaty have been heard, so that that of Cooksley is of interest. In this matter it was held that where a patent for a combination has been restored under the Treaty of Peace Act, the defendants, being found to have assembled parts after the restoration, were held to have infringed the combination patent.

A "master and servant" case was decided in which a verbal agreement made prior to the plaintiff entering the defendants' employment was held to be established to the effect that the defendants should during such service have a licence to use plaintiff's invention relating to winches and to pay a royalty to be settled by arbitration. The defendants having refused to go to arbitration, the plaintiff was entitled to a reasonable royalty.

The House of Lords held that a guard for a motor vehicle consisting of a frame or the like carried along the side of the vehicle and crossing the path of the rear wheels at a slight inclination as used by the London General Omnibus Company, was invalid for want of subject matter.

A vacuum cleaner patent in which the cleaner consists of a single-acting bellows, the upper end of which is provided with a handle, and is slidable with the handle on a central rod secured to the bellows, the lower end forming part of a chamber containing a porous bag with a lid provided with a tube extending into the bag and receiving a nozzle was held to be valid and to be infringed by a somewhat similar construction.

An interesting case which caused a considerable amount of argument was that relating to a rotary engine with toothed plates arranged in the form of continuous helices as distinct from stepped helices shown in a prior specification. It appeared that the plaintiffs having the continuous helix form, thought they were the first to provide continuous expansion, but at the trial it was proved that their engine did not give any new result and the patent was defeated.

Several actions took place with respect to trademarks or trade names and as a matter of record the following may be noted with interest:—

Crossley—for gas and oil engines and gas-generating plant.

Diamond, &c.—for motor-cars and motor trucks.

Hotpoint—for electrical appliances.

Perry—for free-wheel clutches and driving chains for cycles,

and a series of words such as Eusalax, for chemical preparations.

NOTES.

A Turbulence Indicator.

Observations on the discharge of the Nile as deduced from the flow through the sluices at Aswán and from current meter observations upstream, have in certain cases been found to be inconsistent with each other, the discrepancy amounting at times to as much as 20 per cent. The lack of agreement has been attributed to turbulence in the stream at the section where the meter observations were taken. The meters are, in fact, calibrated by towing them at known speeds through still water, and thus if used in highly turbulent water misleading readings may be obtained. From theoretical considerations, Mr. Craig, of the Egyptian Survey Department, has concluded that any error thus arising must be such as to cause an over-estimate of the discharge. In a report recently published by the Ministry of Public Works, of Egypt, Mr. E. B. Wade describes researches undertaken to clear up the anomaly. By the use of a turbulence indicator he has devised, it appears that the suitability of a proposed site for current meter observations can be tested. This turbulence meter is essentially an ordinary current meter with its customary "propeller" replaced by one of infinite pitch. Hence in a steady stream free from turbulence this propeller will not move. In a turbulent stream, however, where the direction of flow is ever varying and may differ at different levels, the "propeller" will tend to rotate at one moment in one direction, and at the next in the opposite way. By fitting a ratchet on the shaft rotation is prevented save in the one direction, and thus in waters which are unsuitable for measurements by a current meter, this turbulence indicator will give positive readings. Experiments made with this instrument indicate that discharges obtained by current meters will be reliable at sites where this instrument gives null readings.

Revised Regulations for the Use of Wood-Working Machinery.

The draft regulations, issued by the Home Office on the recommendation of the Joint Industrial Council for the Building Trade on September 3, 1920, met with considerable criticism at the hands of employers in the various industries concerned. The points raised have been considered by the department, and a revised draft of the proposed regulations has now been issued, in which substantial modifications have been incorporated. It is hoped that as the revised regulations go far to meet all the substantial objections to the former draft, they will now be accepted by all the parties concerned, so that the necessity for a formal inquiry may be avoided. The complete regulations are too long for us to quote, but they all refer to matters bearing upon the safety of the operators and do not now appear to demand any unreasonable practice or equipment in wood-working shops. They apply equally to the employer and the employee, the latter having to use and maintain in proper adjustment the guards and other appliances provided for his safety. Should there be any objections to the regulations in their present form, these must be put in writing, and sent to the Home Office before January 24, together with a statement of the amendments desired. Copies of the revised draft, together with a memorandum on the same, may be obtained on application to the Factory Department, Home Office, London, S.W. 1.

The Validity of a Trade Union Amalgamation.

The amalgamation in 1919 of the Sheet Iron Workers and Light Platers Society and the Boilermakers Society appears to have resulted in serious dissensions within the amalgamated society which have now reached a crisis. A circular has been issued to Sheet Iron Workers above the signature of Mr. Alexander Richmond, who was a prominent official of the Sheet Iron Workers and Light Platers Society. It is issued in the name of a provisional committee of Sheet Iron Workers, and contains the following significant paragraphs:—"The relationship existing between the boilermakers' society and sheet iron workers throughout the country having in no way improved, a meeting of the Sheet Iron Workers' Committee, which had been in negotiation with the Executive Committee of the Boilermakers' Society, was held in the Masonic Hall, Overnewton, Glasgow, on Sunday, December 18, and after the situation had been most carefully and exhaustively considered the following resolution was adopted: That this committee, representing sheet iron workers who are at present contributing to the funds of the United Society of Boilermakers and Iron and Steel Shipbuilders, having been advised by competent legal authorities that the amalgamation between that body and the Sheet Iron Workers and Light Platers' Society, carried out as at September 30, 1919, is contrary to the provisions of the Trade Union Acts, 1876 to 1917, and therefore null and void; and, acting upon the mandate held by them when meeting the Executive Council of the Boilermakers' Society in Newcastle on November 24, 1921, hereby resolve that the functions of the Sheet Iron Workers and Light Platers' Society as a separate trade union shall be immediately resumed, and that arrangements be made with the least possible delay to permit of sheet iron workers contributing to their own organisation, the date from which such contributions to be reckoned being Monday, December 26, 1921. That the making of arrangements necessary to permit of sheet iron workers' branches again operating as branches of an independent union, and the recovery of funds and effects of the Sheet Iron Workers and Light Platers' Society handed over to the Boilermakers and Iron and Steel Shipbuilders' Society as at September 30, 1919, be remitted to a sub-committee." The grounds on which the committee have been advised that the amalgamation of the two societies is null and void are not disclosed in the circular, but the reference to the Trade Union Acts of 1876 and 1917 seems to suggest a possible clue to the mystery. It is provided in the Trade Union (Amalgamation) Act, 1917, that any two or more trade unions may become amalgamated as one trade union if in the case of each union, on a ballot being taken, the votes of at least 50 per cent. of the members entitled to vote are recorded, and of the votes recorded those in favour of the proposed amalgamation exceed by 20 per cent. or more the votes against the proposal. It may be, therefore, that the provisional committee which issued the circular believe that the requisite majority in favour of the amalgamation was not obtained, and challenge the validity of the amalgamation on that ground. This, however, is mere surmise, as we have no information on the point. In any event it seems unlikely that the boilermakers will acquiesce tamely in the attempted dissolution of the amalgamation, and we shall not be surprised if in the end the parties have to resort to the law courts for a settlement of the dispute.

Drop Hammers and the Law of Nuisance.

The case of alleged nuisance arising from the use of drop hammers in Kinning Park, Glasgow, which was the subject of an article in our issue of December 17, 1920, was recently brought on appeal before the First Division of the Court of Session. The defendants, Messrs. Charles McNeil, Limited, hydraulic forge masters, had installed six heavy drop hammers ranging from 15 cwt. to 5 tons in their premises at Kinning Park, Glasgow, and it was alleged by the finance board of the Roman Catholic Arch-diocese of Glasgow, and certain other parties, that the use of the drop hammers constituted a nuisance. Lord Blackburn held that this had not been proved, and the plaintiffs appealed. The Lord President of the Court of Session said that the law of nuisance was designed to protect the use and enjoyment of property free from all interference and annoyance, but this had to be accommodated to the rule which required considerable sacrifice of individual comfort as the price of the advantages which close neighbourhood to others, and to remunerative employment, brought with it. The local clergymen, schoolmasters and other brainworkers in an industrial community such as Kinning Park must obviously perform their professional work under great disadvantages, but it was not enough to say that the use of the hammers put them to serious disadvantage. The annoyance must be destructive of the ordinary comfort of life, and therefore, although it was proved that the thud of the hammers caused sensible annoyance to the resident clergy and to the teaching staff in the adjoining Roman Catholic school, His Lordship thought that the evidence was insufficient to establish that such share of the ordinary comfort of life as the industrial character of the locality afforded to the occupants of the plaintiffs' property prior to the advent of the drop hammers was so materially impaired by their operation as to amount to a nuisance. He thought, however, that if the night working of the hammers had been persisted in it might have amounted to a nuisance. The other judges came to the same conclusion, and the appeal failed.

THE LATE DR. EDWARD HOPKINSON.

A very large circle of engineers will regret to hear of the death of Dr. Edward Hopkinson of Manchester, which occurred at his home at Alderley Edge on Sunday last, the 22nd inst.

Edward Hopkinson was one of a family which has come to be well known among engineers. He was the fourth son of Mr. John Hopkinson, a member of a well-known firm of Manchester engineers, and who was distinguished as an engineer, and was at one time mayor of Manchester. A brother of Edward's, Sir Alfred Hopkinson, was for many years vice-chancellor of Manchester University. Edward was born in May, 1859 and was connected with Manchester for practically all his life. He was educated

at Owens College, where he became Dalton mathematical exhibitioner. In 1877 he proceeded to Cambridge where he gained an exhibition in mathematics at Emmanuel College, and later won a foundation scholarship. In 1881 he was tenth Wrangler in the Mathematical Tripos, and in that year he also took the degree of Doctor of Science in the University of London, specialising in the mathematical treatment of electricity and magnetism. In 1883 he became a Fellow of his college.

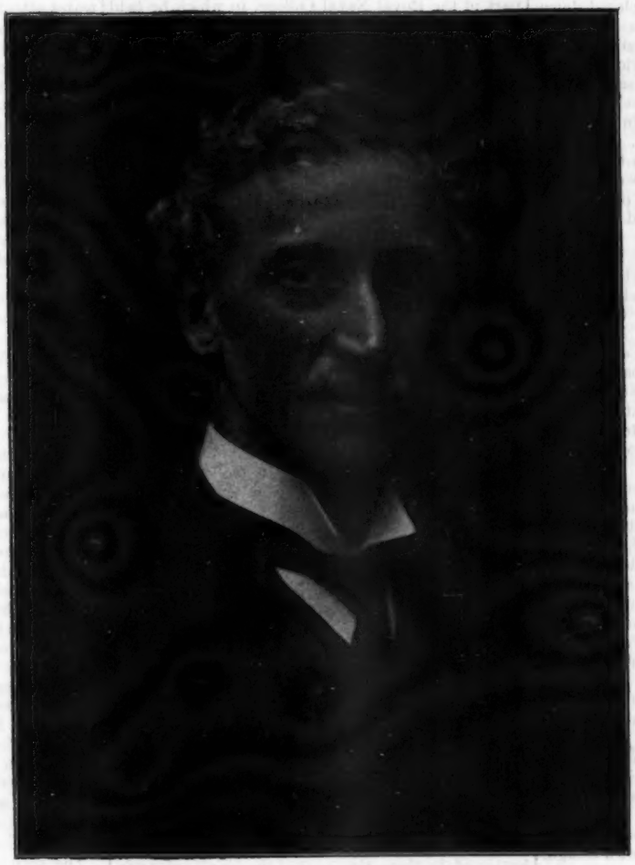
Dr. Edward Hopkinson's practical work commenced when, at the age of twenty-three, he became personal scientific assistant to the late Sir William Siemens. He was connected with a good deal of experimental work on the Portrush and Bushmills railway, the first line in the United Kingdom to be electrified, and having also the distinction of being operated by hydro-electric power. The experimental work done in this connection formed the subject of a paper which Edward Hopkinson read before the Society of Arts in 1883. Shortly afterwards it was proposed that a line from Bessbrook to Newry which had been decided upon for the carriage of flax from wharves to the mills, should be worked electrically. Dr. Edward Hopkinson was consulted in the matter and designed the equipment, and his proposals were accepted, the company agreeing to purchase the equipment, if after six months experience the working was found to be more economical than that of a similar steam line. The line was opened for traffic in 1885, and the conditions were admitted to have been complied with by April, 1886. The motor cars were fitted each with an Edison-Hopkinson motor fixed to the leading bogie frame and driving one axle by chain and sprocket. The generating station contained an inward flow vortex wheel deriving its supply from the Camlough, the available head being 28 ft. This wheel was arranged on an horizontal shaft from which two dynamos were driven by belts. This machinery was constructed by Messrs. Mather and Platt, Manchester, which firm Dr. Hopkinson had joined in 1884, to take charge of their electrical department. The electrification of this line was described by Dr. Hopkinson in a paper read before the Institution of Civil Engineers in 1887 for which the author was awarded a Telford Medal and a Telford Premium. We may perhaps add here that in 1886 jointly with his elder brother, the late Dr. John Hopkinson, F.R.S., Edward contributed a paper on "Dynamo-Electric Machinery" to the Royal Society.

Dr. Edward Hopkinson's connection with Messrs. Mather and Platt continued up till the time of his death. In 1887 he was made a partner in the firm, and when the latter was formed into a limited company he became one of the managing directors. In 1899 he was appointed vice-chairman. He was also vice-chairman of the Chloride Electric Storage Battery Company.

Another important work for which Dr. Hopkinson was responsible was the electrical equipment of the City and South London Railway—the first of the "Tubes"—opened in 1890. This was the most important application of electricity to railway working up till that time, and was notable for the fact—among others—that the locomotives were constructed with the motor armatures mounted direct on the axles—now common practice, but then an innovation, though it had been suggested some years previously by Sir W. Siemens. The electrical equipment was furnished by Messrs. Mather and Platt, and the whole of this part of the railway undertaking was described by Dr. Hopkinson in a paper read before the Institution of Civil Engineers in 1893, the author receiving in this connection a Telford Premium and a George Stephenson Gold Medal. He was also responsible for the electrical equipment of the Douglas and Laxey Tramway, and of the Snaefell Mountain Railway. On the latter there is a grade of 1 in 12 for four miles, and the motor cars were fitted with a motor for each axle.

It is impossible to refer to all the works with which Dr. Hopkinson was connected, and we have above confined ourselves to undertakings which marked distinct advances in the pioneer days of electric traction.

Becoming a member of the Institution of Mechanical Engineers in 1894 Dr. Hopkinson was for some time a member of Council and finally was elected to the presidential chair in 1919. It was greatly regretted that a long illness prevented him from taking the active part he wished to in the proceedings during his presidency. His address dealt with a number of topics such as the influence of the war on production; the necessity for first-class administration and organisation, and included a review of engineering industry and the position of engineers in India. The latter was the result of first-hand investigations made during 1916–18 when Dr. Hopkinson was a member of the Indian Industrial Commission. That commission, it may be remembered, advocated the foundation of a representative society of engineers for India; this suggestion has lately materialised in the Institution of Engineers (India) which bids fair to be a very useful body. Elected an associate member of the Institution of Civil Engineers in 1885 Dr. Hopkinson was transferred to full membership in 1890 and he subsequently served on the Council. He was also at one time President of the Manchester Association of Engineers, and was on the Council of the Institution of Electrical Engineers, and first chairman of the Manchester section of the latter. He was also vice-president of the Manchester Steam Users' Association. Among other important positions connected with the profession Dr. Hopkinson was a member of the Industrial Research Board of the Department of Scientific and Industrial Research, and was a member of the Court of Governors of Owens College, Manchester.



Photograph by F. W. Schmidt.

Edw. Hopkinson

It was a considerable source of satisfaction to engineers when Dr. Hopkinson was elected Member of Parliament for the Clayton Division of Manchester in 1918. The profession does not send many of its members to Parliament, and in Dr. Hopkinson they felt they were worthily represented. In the difficult times of re-adjustment since the war Dr. Hopkinson has frequently given a lead in the Press and through other channels on the economic questions on which the country had to a large extent lost all sense of proportion.

Dr Edward Hopkinson was an enthusiastic mountain climber and a well-known member of the Alpine Club. He was connected with many philanthropic organisations in Manchester and its neighbourhood, and had been treasurer and chair-

man of committees for the Salford Royal Hospital. He leaves a widow, Minnie, eldest daughter of the late John Campbell of Rathfern, Co. Antrim, and a son and daughter, to whom sympathy will be extended in their loss.

THE MINERAL RESOURCES OF BRAZIL.

A REPORT, just published, by Mr. E. Hambloch, Commercial Secretary to H.M. Embassy, Rio de Janeiro, shows that there is a good wolfram deposit in the municipality of Encruzilhada, Rio Grande do Sul; this was formerly worked by a German company, and the product was shipped to Germany; but though the deposit appears to be good, it is no longer worked. In the neighbourhood of this wolfram deposit there is a tin mine formerly worked by a Belgian company, but now also closed down. Very few investigations as regards petroleum deposits have been carried out in Brazil, but it is supposed that such deposits exist in various States; a British syndicate has recently contracted a property in Rio Grande do Sul for the development of shale oil, and it anticipates that within two years 1,000 tons of shale will be retorted daily. Work has been done during the last two years in the further investigation of the enormous iron ore deposits in Brazil, and various schemes have been propounded for exporting the ore to American and European markets.

The Itabira Iron Ore Company, at Itabira de Matto Dentro, proposes to erect iron and steel works, using foreign coal as fuel. In this connection, it is interesting to note that much anxiety has been shown in regard to having the iron ores smelted in the country, and Congress has extended for a further period of two years existing laws by which the Federal Government is empowered to grant favours and give encouragement to locally-manufactured iron and steel. The States of Minas Geraes, São Paulo and Rio de Janeiro have also passed laws encouraging this industry. The report gives general information on Brazilian, Belgian German and British enterprises for the manufacture of iron and steel in the country; it adds "opinion in Brazil is becoming convinced that the future of this industry lies in the electrical smelting of ore with charcoal obtained from the plantations of eucalyptus; no process has yet been developed for economically obtaining coke from Brazilian coal, and foreign coal will always be too dear and would, besides, detract from the independence of the industry."

The processes for the direct smelting of steel from the iron ore have attracted great attention in Brazil, and an electric furnace is being put down at Juiz de Fora, Minas Geraes, to smelt steel direct by an Italian process. It is satisfactory to read that a considerable amount of research work has been done at the Ouro Preto School of Mining; this institution has been successfully smelting ferro-manganese in an electric furnace of its own design. In the matter of manganese, the report confirms the purchase by the United States Steel Corporation of the Morro da Mina mine, the largest manganese mine in Brazil; as a result of this purchase and the fall in prices, all other mines have closed down with the exception of two. Further, the State export tax on manganese ore has been increased, the freight rates have advanced also, and the combination of these two factors makes it unprofitable to mine manganese ore in Brazil for the time being. Brazil produces excellent sheet mica; her gold production varies annually between 4 tons and 5 tons. As for copper, surveys show that large quantities are available. Great attention is being directed to the development of hydraulic power in the country for the electric smelting of iron and steel, and for use in electrifying Brazilian railways; there is little doubt that in both applications large developments are to be expected in the future.

THE WOMEN'S ENGINEERING SOCIETY.—A series of three lectures will be given at the club room, 26, George-street, Hanover-square, W., at 6.15 p.m., followed by discussion—on January 24, by Miss Gwynne Howell, on "Domestic Engineering"; on February 21, by Mrs. H. Irving, on "Model Experiments in Aeronautics"; on March 14, by Mr. F. S. Button, on "Woman's Place in Industry." Tickets may be had on application to the secretary of the society at the above address.

THE LATE PROFESSOR J. H. COTTERILL.

PROFESSOR JAMES HENRY COTTERILL, M.A., F.R.S., was the youngest son of the Rev. Joseph Cotterill, of Blakeney, Norfolk. He was born in 1836, and died on January 8, 1922. Educated at Brighton College he, partly for reasons of health, went through an apprenticeship in the works of Messrs. Fairbairn, of Manchester, and the insight then obtained into practical engineering was serviceable in his later teaching. He then went to St. John's College, Cambridge, and took a fairly good position in the Mathematical tripos. In 1866, he became Lecturer, and in 1870, Vice-Principal of the Royal School of Naval Architecture and Marine Engineering, then at South Kensington. In 1873, the school was moved to Greenwich and became part of the Royal Naval College, in which he held the position of Professor of Applied Mathematics till his retirement in 1897.

The Royal School of Naval Architecture at South Kensington, the third school established by the

THE LATE PROFESSOR J. H. COTTERILL.

Admiralty for the training of its constructors and engineers, had through the distinguished careers of its students, exercised a very important influence on the shipbuilding industry in this country and on the development of the great Navy which commanded the seas during the late war. The organisation of the theoretical part of the courses of study was mainly due to the remarkable ability, industry and originality of Professor Cotterill. He was an admirable teacher, clear and accurate. It needs only to mention Sir William White, William Johns, Sir Francis Elgar, Sir Philip Watts, and Richard Sennett, all students at Kensington, to understand how profound the influence of the school has been. Although primarily intended for Admiralty students, the school was open to private students, and some of these obtained important positions in private shipyards and in the constructive department of foreign navies.

Professor Cotterill's earliest scientific papers were on the "Principle of Least Action," in the *Philosophical Magazine*, and some articles on the "Theory of Propellers" and the "Re-action of an Elastic Fluid issuing from an Orifice," in the Annual of the School of Naval Architecture. In 1878, he published a treatise on the Steam Engine, considered as a Thermodynamic Machine; and in 1884, a treatise on Applied Mechanics. Both these passed through several editions. The Applied Mechanics especially, based on a large teaching experience, from its clearness and comprehensiveness has remained a classical text-book and has affected the treatment of the subject in British and American engineering schools.

LITERATURE.

Fifty Years of Electricity. The Memoirs of an Electrical Engineer. By J. A. FLEMING, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in the University of London. The Wireless Press, Limited. [Price 30*s.* net.]

IT was a happy thought of Professor Fleming to construct a panorama in which we might see depicted the mechanical growth and theoretical development of electrical science. He takes us through successive mutations of electrical progress, so momentous in their effects and operations, that they can hardly be conceived as being contained within the span of any single life. Yet a very few pages are sufficient to review and dismiss the history of electricity prior to 1850. The author concentrates attention on the last fifty years, during which he himself has played a prominent part in what he so well describes. The successful side of invention is painted in very bright colours. We applaud the efforts that have promoted development, and appreciate the business acumen and driving-power which has ever been ready to convert scientific ideas into operative agents of public utility. We would willingly have learnt something more of the difficulties that have stood in the way of achievement. From the author's point of vantage, he must have known, not only the successes that have rewarded invention, but the disappointments that have dogged the display of energy and endeavour. The history of failure, if it could be written, would not prove uninstructive.

We are invited to consider the day of small beginnings, when in the field of telegraphy, for example, a Wheatstone A.B.C. transmitter satisfied the requirements of the business world, to follow the progress accomplished by the construction of the Hughes Printing Telegraph, and to admire the delicacy of the Thomson Mirror Galvanometer, that made the working of submarine cables possible. Numerous inventions in dazzling succession, bridging distance and facilitating intercourse, are seen displacing or supplementing earlier efforts. The complications appear bewildering and the construction grows intricate, but as the author well points out, the drift of invention has been towards devising machines, which dispense with the necessity for a highly-skilled telegraphic operator, substituting an ingenious machine which can be worked by any girl or boy who can manipulate an ordinary typewriter. To-day sees the culmination of this effort to supplant intelligence by mechanical device, in the perfecting of the automatic system of communication by telephone, which is "the nearest approach the human mind has yet made to the construction of an artificial brain, with its ganglion switches, copper wire nerves, electric current circulation and electromagnetic muscles, all controlled by an unseen intelligence, the distant subscriber."

The plan of the masterly sketch that tells the progress of the electric telegraph is followed by that which traces the growth of the dynamo, alternator, transformer and motor. We are reminded of Faraday's great discovery, whereon rests the possibility of dynamo construction, that an electric current could be generated in a wire or conductor merely by moving it in a strong magnetic field near the poles of a magnet, so as to cut across the lines of magnetic force. This was in 1831, and in the same year H. Pixii produced a machine for generating an alternating current by the rotation of a permanent magnet in front of bobbins of wire. It is not often that technical application follows so swiftly on scientific announcement. We have travelled far since those days, but the road has not been easy or smooth. Breakdowns and failures, especially in electrical insulation, marked the days of early attempts, and it has been only by intensive study that the dynamo has been brought to the condition of being a highly efficient energy transformer of 90 per cent. to 95 per cent. efficiency, capable of long non-stop runs without overheating or failures, mechanical and electrical.

Electric lamps and electric lighting emphatically belong to the period of Professor Fleming's experience. There were lamps before 1870, but they remained a scientific experiment, or a source of

illumination for the curious. For long the problem of producing a small unit of light for domestic purposes by means of an electric current—dividing the electric light as it was called—remained unsolved. We are reminded here of the work of Edison, Sir J. Swann, and a host of others, who have successfully attacked this question. But with all the ingenuity expended, our sources of artificial light are inefficient. In the carbon filament lamp, out of all the power given to the filament to heat it, only about 3 per cent. is used in creating radiation which can affect the eye as light. In the vacuum tungsten lamp, 7·5 per cent. is utilised, and in the ½-watt gas-filled lamp, one of the latest productions, the efficiency is higher. We are still far from reaching the efficiency attained in the dynamo and electric motor as energy transformers, and a vast field lies open for research in the endeavour to discover practical sources of artificial illumination, which will bring the lamps on a level as regards efficiency of transformation with such appliances.

From lighting to heating and cooking is an easy step, but in ordinary houses little advance has been made in this direction, mainly because the price of the unit of electrical energy is prohibitive. It is to be feared that the action of past Governments has retarded the use and application of electricity in many of the arts and industries by legislative shackles. Domestic use has suffered severely, and it will be some time before electricity will supplant coal or, even, gas as an efficient substitute, and avoid the inconvenience of dirt, dust and labour inseparably connected with the use of coal. The author, however, is hopeful, and he looks forward confidently to the time when heating will be effected either by gas with high calorific power, prepared exclusively for heating, or the employment of electric energy with all its great inducements in respect of safety and cleanliness.

A large and important section is devoted to wireless telegraphy and telephony, processes with which the author is so closely identified. Needless to say the evolution of this system of communication is traced in a very illuminating manner, by the master's hand. We can follow with admiration the progress from the day that saw the plans for the first 25-h.p. radio station drawn on the author's lecture table at University College, to the time when the world is covered with large power stations for transmitting round the Globe electric waves of high energy for telegraphic purposes, "employing thousands of horse-power and exhibiting in every part, the results of scientific thought and invention, the outcome of very costly experiments by numerous talented radio engineers and experts."

Hochleistungskessel. By Dr. Ing. Hans Thoma. Berlin: Julius Springer. [Price 117 marks.]

Dr. Thoma's volume is not a descriptive treatise on high-capacity steam boilers. He characterises his publication as dealing with experimental studies on heat transference, on draught, and on the economical and practical limits in increasing the capacity of boilers. The experiments were made at the Technical High School of München, where he is now working; his experience was acquired in the ship-building works at Wilhelmshaven. The way in which he studies the transference of heat from the hot gases to the water tubes by means of streamlines is somewhat novel. In its simplest form his apparatus consists of a shaft through which air is drawn upward by a fan. In the lower, wider portion strips of blotting paper are suspended, which dip into diluted ammonia; higher up the shaft forms a rectangular glass cell below which is a nozzle of trumpet shape, made of stout paper soaked in hydrochloric acid. The cell is placed between a lantern and a camera, and instantaneous photographs are taken of the fumes of ammonium chloride. On the plate the direct air current from the nozzle appears dark and bounded on both sides by streams of fumes; the discontinuity surfaces are in constant turbulence which becomes more and more periodic as the air speed is raised, from 0·7 m. per second to 4 m.

In order to study the deflection of the fumes by spherical or tubular bodies, Thoma prepares a sphere or short cylinder out of clay or paper stuff, soaks it in hydrochloric acid and places such bodies in his glass cell, 150 mm. by 150 mm. in cross section, so that the fumes play about the outsides of the bodies. He thus produces a model of a section of a tubular boiler, in which the tubes may be arranged in vertical rows or in staggered horizontal rows, at varying distances apart. Looking at his photographs we see that every tube is surrounded by a cushion of vapours which extends into a dead space above the tube. When the tubes are vertically above one another the dead space of row 1 may comprise row 2. When the tubes are staggered, the dead spaces are contracted, and the fume columns rising from the tubes remain separated from one another as before. The experiments suggest that it is advisable to stagger the tubes, to group them a little asymmetrically and to add baffles in order to secure a good play of the flames on the tubes.

It will be noticed that these stream-line studies differ from those ordinarily made with smoke particles in which the smoke is produced at one end of the channel or shaft and travels right through it. Dr. Thoma introduces the ammonia at the entrance; but the ammonia finds the acid at each part of the tube it comes in contact with. That is the novelty of the investigation; the use of ammonium chloride fumes is, of course, very old.

In some further experiments Dr. Thoma modified his apparatus. He wished to study the gas currents in Sturtevant radiators, in which hot steam flows through the tubes and heats the air outside, whilst in a tubular boiler the hot gases heat the water in the tubes. For this purpose he formed his radiator bodies as before, but he impregnated them with phosphoric acid which is not volatile like hydrochloric acid. He therefore determined the loss by weight of ammonia and the neutralisation of the acid in the various bodies, and from these data he deduced the Reynolds coefficient $w d/v\eta$ (usually written pvd/μ in this country) where d is the diameter of the tube and w, v, η are the velocity, specific volume and viscosity of the gas.

Dr. Thoma checks these measurements and deductions as far as possible with the aid of the results of tests, made by Fuchs on a Steinmüller boiler, with superheater, and by Rietschel on a Sturtevant radiator, but he regrets that he could not find any further detailed data as to thermal flow and efficiency, pressure, velocity, &c. He arrives at the conclusion that in a boiler the first horizontal row of tubes takes up little heat, the second row takes up most, and the higher rows less and less in succession; it does not appear, however that he dealt with more than five rows in his experiments. He concludes that the tubes should be staggered, and not be too close to one another, being separated by spacings about equal to their diameter. The heat transference he finds approximately proportional to the 0·6 power of the velocity of the gases.

So many assumptions have to be made in these deductions that the reader may consider Dr. Thoma to be on firmer ground in the second part of his book, in which he deals with constructive and economical features, draught, turbo-blowers, chain grates, combustion chambers, grate area, heating surfaces, boiler cleaning and feed water heating. He is in favour of amply dimensioned combustion chambers and points out that superheater tubes should be so arranged that no bends of small radius of curvature occur. He has had some peculiar troubles with fine ashes settling on vertical tubes, and he removes these by steam jets; he says more on the external cleaning of boiler tubes than on their internal cleaning. The octavo volume of 116 pages is well illustrated.

BOOKS RECEIVED.

Medical Research Council. Reports of the Industrial Fatigue Research Board No. 15. *Motion Study in Metal Polishing.* (Metal Series No. 5.) By E. Farmer, M.A., assisted by R. S. Brooke, M.A. London, Manchester, Cardiff and Edinburgh: His Majesty's Stationery Office. [Price 2*s.* net.]

The Adjustment and Testing of Telescope Objectives. London and York: T. Cooke and Sons, Limited. [Price 12*s.* 6*d.* net.]

The Metallurgy of the Common Metals, Gold, Silver, Iron (and Steel), Copper, Lead and Zinc. By Leonard S. Austin. Fifth edition, revised and enlarged. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Limited. [Price 42*s.* net.]

The Book of the Ford Van. By R. T. Nicholson, M.A. Second edition, revised. London: Temple Press, Limited. [Price 3*s.* net.]

The Framework of Wireless Telegraphy. A New Theory of Electric Wave Sources and Propagations, with Rational Applications. By R. C. Galletti di Cadilhac. Appendix. *Origin of Quanta, Magnetons and Light. Electric Disclosure of Gravity and Kinematics of Matter.* London: Crosby, Lockwood and Son. [Price 3*s.* 6*d.* net.]

Department of Scientific and Industrial Research. The Physics and Chemistry of Colloids and their Bearing on Industrial Questions. Report of a General Discussion held jointly by the Faraday Society and the Physical Society of London, on October 25, 1920. London, Manchester, Cardiff and Edinburgh: His Majesty's Stationery Office. [Price 2*s.* 6*d.* net.]

Patents and Chemical Research. By Harold E. Potts, M.Sc. Liverpool: University Press. [Price 8*s.* 6*d.* net.]

The Analysis of Coal and Its By-Products. By S. Roy Illingworth, M.Sc., A.R.C.Sc., F.I.C., assisted by Jenkyn Griffith, F.C.S. London: *The Colliery Guardian*, Company, Limited. [Price 21*s.* net.]

Een Nieuwe Hydraulische Trekkrachtmeter. By Ir. M. W. Polak. Wageningen: H. Veenman.

Meteorological Office—Air Ministry. Report on the Distribution of Rain in Space and Time over the British Isles during the Year 1920. London, Manchester, Cardiff and Edinburgh: His Majesty's Stationery Office. [Price 12*s.* 6*d.* net.]

Die Warmwasserbereitungs und Versorgungsanlagen. Ein Hand und Lehrbuch für Ingenieure, Architekten und Studierende. By Wilhelm Heepke. Second edition, revised and enlarged. München and Berlin: R. Oldenbourg. [Price 120 marks.]

The British Journal Photographic Almanack and Photographer's Daily Companion, 1922. Edited by George E. Brown, F.I.C. London: Henry Greenwood and Co., Limited. [Price 2*s.* net.]

An Introduction to Applied Geography. By Alexander Stevens, M.A., B.Sc. London, Glasgow and Bombay: Blackie and Sons, Limited. [Price 6*s.* net.]

Railway Statistics of the United States of America for the Year ended December 31, 1920, *Compared with the Official Reports for* 1918, *and Recent Statistics of Foreign Railways.* Prepared by Slason Thompson. Chicago, Ill.: Bureau of Railway News and Statistics.

Fire Prevention and Fire Protection as Applied to Building Construction. A Handbook of Theory and Practice. By Joseph Kendall Freitag, B.S., C.E. Second edition, revised. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Limited. [Price 30*s.* net.]

How the Hague Rules affect Merchants. By Andrew Eric Jackson, O.B.E., M.A., LL.D. London: Effingham Wilson. [Price 2*s.* 6*d.* net.]

Practical Electricians' Pocket Book, 1922. Edited by H. T. Crewe, M.I.Mech.E. London: S. Rentall and Co., Limited. [Price 3*s.* net.]

Application de la Résistance des Matériaux au Calcul des Avions. By M. Boileve. Paris: Gauthier-Villars et Cie. [Price 30 francs.]

United States Coast and Geodetic Survey. Serial No. 150. *Modern Methods for Measuring the Intensity of Gravity.* By Clarence H. Swick. Washington: Government Printing Office. [Price 15 cents.]

The Institute of Metals.—The annual meeting of the Institute will be held in London on March 8 and 9, when ten important papers are to be presented for discussion. At the annual dinner at the Trocadero Restaurant on Wednesday, March 8, lady members, as well as many distinguished guests of the council, will be present. Prior to the March meeting a ballot for the election of new members and student members will be held. The necessary membership application forms, combined with an interesting illustrated booklet describing the work of the Institute, and including photographs of all past-presidents, can be obtained from the Secretary, Mr. G. Shaw Scott, 14, Members'-mansions, Victoria-street, Westminster, S.W. 1, to whom application forms, duly completed, should be sent not later than noon on February 22. The annual May lecture will be delivered on May 3 by Sir Ernest Rutherford, F.R.S., on "The Relation of the Elements." The discourse should deal with the much-debated subject of the possible transformation of one metal into another. The autumn meeting will be held—for the first time—at Swansea on September 20 to 22.

Competition for the Design of Traps.—The Council of the Royal Society for the Prevention of Cruelty to Animals have announced a competition for an improved design of rabbit trap, in connection with which prizes of 150*l.* and 50*l.* are to be offered. What is wanted is an effective and humane substitute for the barbarous steel gins so often used, which mangle the limbs of the animal and hold it until pain, starvation or the keeper puts an end to its sufferings. Models of the competing designs must be sent carriage paid to the Secretary of the Royal Society for the Prevention of Cruelty to Animals, 105, Jermyn-street, London, S.W., before March 31 next, from whom all further particulars may be obtained. The successful model will remain the property of the inventor who will retain the whole of the rights in his invention. We trust that, if only in the interests of humanity, those of our readers who are conversant with the habits and mental processes of our small wild animals will endeavour to assist the society by devising a form of trap which will either kill rabbits outright or hold them without causing suffering. The conditions of the problem are difficult, but it is well worth making an earnest attempt to solve the question.

INDUSTRIAL NOTES.

THE United States Department of Labor has issued a report, No. 279, on the Hours and Earnings in Anthracite and Bituminous Coal Mining. From this we quote the following classification. "Miners (company, inside, anthracite)" very seldom mine coal; they operate electric or compressed air machines, drill holes into stone or coal for explosives, and load cars. They are usually engaged in removing obstructions in the mines and in prospecting for profitable mining chambers. They are paid a time rate which is a little less than that of a consideration miner, and are called "company miners" to distinguish them from the consideration miner. "Miners (consideration, inside, anthracite)" operate electric or compressed air coal mining machines, drill holes into coal or stone for explosives, and also load coal into cars. They are regular "contract miners" who, in consequence of obstructions in their working chambers or rooms, such as stone, slate, dirt, or of bad working conditions, are unable to earn on a tonnage basis an amount equal to or in excess of a certain specified rate per day. They are paid the specified rate, which is a little more than that of company miners, until they are able to earn more on a tonnage basis. "Miners (contract, inside, anthracite)" operate electric or compressed air coal mining machines, drill holes into coal for explosives, and also load coal into cars. They are paid on a tonnage basis. A contract miner becomes a consideration miner when, owing to obstructions in his working chamber or room, such as stone, slate, or dirt, he is unable to earn an amount in excess of a fixed or specified rate per day. He then is paid the fixed rate per day until he is able to earn more on a tonnage basis. "Miners (hand or pick, inside, bituminous)" undercut coal with pick, cutting some distance from the face of the vein, separate it from veins with pick or explosives, and load the coal into cars. "Miners (machine, inside, bituminous)" operate electric or compressed air coal mining machines, undercutting veins of coal and drilling holes into coal for explosives.

THE average full-time hours per week is 48. The average earnings per hour were as follows:—Company miners, anthracite, in 1919, 0·582 dols.; in 1920, 0·576 dols. Consideration miners, anthracite, in 1919, 0·634 dols.; in 1920, 0·659 dols. Contract miners, anthracite, in 1919, 0·841 dols.; in 1920, 0·925 dols. Hand miners, bituminous, in 1919, 0·785 dols. Machine miners, bituminous, in 1919, 0·926 dols. The above figures were obtained by dividing the actual earnings received by the hours actually worked. The report gives for all classes of men in the mines the average full-time hours in a half-month and also the average hours actually worked in the half-month. In the anthracite mines, many of the employees, both inside and outside, are quoted in the tables as putting in more hours of actual work than the average full-time hours in the half-month, and they received in consequence higher pay than the average full-time earnings. This is not the case with any of the miners of the categories above referred to. Further, in the bituminous mines, in the year 1919, every class of man worked less than the average full-time hours.

The Joint Industrial Council of the Printing and Allied Trades of the United Kingdom held a meeting in London last week, when a letter from the Postmaster-General was read, saying that he was not yet in a position to make any announcement as to a reduction of postal rates for printed matter and postcards. The meeting reviewed the disastrous effects which the present postal rates had upon the printing trade in this country, a very large amount of this trade being driven to the Continent, one consequence being that unemployment in the printing and allied industries was becoming worse. The Council therefore decided to impress upon Government, in the strongest possible manner, the necessity of the present postal rates being immediately amended, and asked the Press and the various organisations of employers and employees throughout the country to use their utmost endeavours to assist the Council in attaining this end. The Council is representative of 5,000 employers and a quarter of a million workers.

The ballot of the National Union of Dock Labourers on the proposed amalgamation with the National Transport and General Workers' Union has resulted in the following: For amalgamation, 27,804; against, 1,059, or a majority of 26,745 for amalgamation. There voted, therefore, 28,863; this is equal only to 54 per cent. of the total membership. The enlarged union now comprises workers in road transport, both commercial and passenger, inland waterways, estuaries, rivers, dock and general workers, the membership now being 450,000, a total which may shortly reach half a million by the joining up of other small sections. It is reported that 95 per cent. of the transport organisations of the country are now represented in the National Transport and General Workers' Union.

The General Council of the Trades Union Congress issued last Friday a manifesto to the executives of the affiliated unions, in which they say they are compelled by the attacks now being made on the standard conditions of labour to consider seriously their responsibility. They have decided to consult the unions regarding the action to be taken on a national basis for resisting the efforts now being made by employers to secure an increase in the working day or week. They consider the retention of the shorter working day or week a vital principle of trade union organisation, and have decided to call upon affiliated bodies to give immediate attention to the question of arrangements whereby the full force of trade union movement may be utilised for the purpose of resisting attempts on the part of employers to compel any union or unions to accept an increase in the working day or week. The General Council add that they have no desire to interfere with the ordinary process of negotiations in any industry, and would prefer that the initiative for their intervention on behalf of the movement should come from the responsible negotiating body for the industry involved. They feel, however, that they would not be performing the duties imposed upon them by the Trades Union Congress if during this critical period in trade union history they did not function as a responsible national body. With regard to the question of finance, the General Council suggest that they should be "empowered to impose a levy on the movement if this is found necessary"; and refer to "the depleted state of trade union funds" and to "the state of unemployment in the principal industries," &c. The unions are requested to reply not later than by March 24; in the meantime, the "critical period in trade union history" seems likely to continue.

At a recent meeting of the executive of the Miners' Federation held in London it was reported that the votes of the districts were for the abolition of the office of full-time president, and in favour of a part-time president to be elected annually at the annual conference. Mr. Herbert Smith was asked to continue as acting chairman until a president was nominated to the vacancy created by the resignation of Mr. Robert Smillie. The question of low wages in the coal industry received the attention of the same meeting, and it was decided to approach the coalowners through the National Board with a view to both parties making a joint representation to the Board of Trade, the object being to secure an investigation into the causes making for low wages and to arrive at some drastic improvement.

An example of German business methods is given in the *Journal of Industrial and Engineering Chemistry* for the present month. This journal is published by the American Chemical Society. The article we refer to is entitled "Who Will be Next?" and gives the translation of a letter written on May 25 last by the Commercial Councillor, German Embassy, Rome, to the Minister for Foreign Affairs, Berlin. The letter, which is taken from *Idea Nazionale*, August 28 last, deals with the furthering of German commerce with Italy. It says: ". . . In order that we may create for ourselves a favourable political situation, taking advantage of the discontent of the Italian people, and especially of the Nationalist and Nittian parties, against the Powers of the Entente—a political situation which might in due course be favourable to us when Germany would be faced by fresh complications—it is necessary to strengthen this discontent in order to consolidate our situation through economic action. To this end, the point at which we have arrived is only a quarter of the way. We must create such economic interests and bonds with Italy that, whatever happens, Italy will have to follow our political lead. . . ." The letter further speaks of "inundating the Italian market with German goods," and it adds that "Italian consumers gladly accept cheap articles." The various fields of activity are reviewed in detail. The dyeing trade, for example, in Italy, is "in a precarious state of development, but holds the promise of an assured future. It is, however necessary that in order to follow out in this branch, too, the method of peaceful destruction advised by me, the Italian Government should not take precautions to prevent the import of colouring matters from abroad, as otherwise it is certain that the Italian industry which, it appears to me, are seeking American capital to support them, might assume a more solid position in the Peninsula, a position which it would be more difficult to destroy. . . ." Numerous other unpleasant suggestions are contained in the letter in question, which occupies two closely printed columns of the American journal. The latter is fully justified in asking the question, "Who will be Next?"

We understand that the Lanarkshire Steel Company, Limited, the well-known steel manufacturers, of Motherwell, have decided to resume work in their mills in the course of the next two or three weeks. In view of the enormous amount of unemployment which is at present prevailing in Scotland, this is welcome news, as it will mean that a large number of men will be engaged. In normal times the Lanarkshire company employ something like 2,500 men and, although this number cannot be found immediate employment, it is thought that a good proportion will be taken on.

THE FUTURE OF THE GERMAN ALKALI INDUSTRY.

THE German alkali industry has probably caused more friction, disappointment and difficulties than any of the other large German industries, and at present its position is very precarious. Before the war some 50 per cent. of the entire production was exported, but the war brought this trade to a standstill, and the enormous amount of money and work employed in developing foreign markets appear to have been wasted. Foreign countries have adopted other methods for obtaining their supplies; rich alkali deposits in Spain have been opened out, and, moreover, Germany has lost the alkali works of Alsace, with their excellent deposits.

The future of the German alkali industry has been considered by the "Socialising Commission," and a number of experts—geological, chemical, industrial and agricultural—as well as representatives of the industry itself, have been assisting the Commission. All were agreed that the position of the alkali industry was fundamentally different from that of the coal industry, inasmuch as the production of the latter could not keep up with the demand, whilst there was a very material over-production in the alkali industry. Erratic legislation before the war and the faith in Germany's monopoly gave an impetus to unhealthy speculation.

This monopoly is now a thing of the past, and in order to enable the German alkali industry to compete in the world markets, it will be necessary to close down the works labouring under unfavourable conditions and to confine the production solely to the remainder.

Divergent views have been voiced and different proposals put forward by the commission, but they are all based upon the above principle. Some favoured the proposal of the National Alkali Council, that the present five-yearly valuation of the works for the syndicate allotment should be extended to terms of thirty years. The works closing down should keep their allotments for thirty years, when they would transfer them to other works for compensation. Exploitation of new shafts should be prohibited by law; compulsory closing down of works should be avoided, only the National Alkali Council being empowered to close down factories which continued to work unprofitably. Rathenau proposes the granting of two years for voluntary closing down, at the end of which period all works whose cost of production exceeded by 20 per cent. the average cost of production of the ten most advantageously working concerns should be compulsorily closed down.

Another section recommends a more sweeping reform, proposing a division of the selling and the working organisations, the working to be vested in the German Alkali Combine, comprising a number of experts and interested persons. It is suggested that, by means of premiums, officials and workmen would become interested in attaining the best possible results, and the owners would be compensated by a proportion of shares with some preferential rights.

THE INSTITUTION OF CIVIL ENGINEERS.—The Council of the Institution of Civil Engineers have made the following awards for students' papers read in London or at local associations during the sessions 1919-20 and 1920-21: The James Forrest Medal and a Miller prize to Mr. R. D. Gauld, M.Eng. (Manchester); the James Prescott Joule medal and a Miller prize to Mr. J. E. Dumbleton (Birmingham); Miller prize to Mr. Henry Fowler (Manchester), Mr. G. H. Humphreys, M.A. (Manchester), Mr. C. M. Brain (London), Mr. J. T. Chalk (London), Mr. K. T. Spencer, M.C. (London), and Mr. E. A. Phillipson (London).

ELECTRIFICATION OF BOLOGNA—MONFALCONE LINE.—H.B. Majesty's Consul at Bologna has notified the Department of Overseas Trade that the *Avvenire d'Italia*, published at Bologna, contained the following in its issue of January 6: The Direzione Generale of the Italian State Railways announce that their administration is desirous of receiving tenders for the electrification of the Bologna-Venice-Monfalcone line. The work is to be entrusted to private enterprise. Offers should be sent registered in double envelopes before April 30 to the Direzione Generale Ferrovie dello Stato, Rome, where full details as to the nature of the contract may be consulted.

BALL AND ROLLER BEARINGS: THEIR DESIGN AND PERFORMANCE.*

By A. W. MACAULAY.

THE subject of ball and roller bearings is too wide to permit of anything like a complete survey in the course of one lecture. On this occasion I have endeavoured to deal with it in a general manner, however, in the belief that this will be most acceptable to the Institution. The principal point which requires emphasis to-day is the economic value of the principle when applied to general engineering, and this consequently forms the focus upon which the various branches of the subject are centred.

The outcome of a demand for a really satisfactory self-aligning bearing was the construction illustrated in Figs. 1 and 2. In this case the self-alignment is obtained within the bearing itself, and any tendency of the shaft to deflect or whip is automatically dealt with without causing overload on the balls. This was found to be of the greatest service in transmission work, but the performance of the bearing in many other classes of machinery caused it to be subjected to careful investigation, and the result of recent research has somewhat modified the earlier views on the subject.

The ball bearing being based on the principle of rolling motion, the maximum efficiency is obtained when the relative slip between the ball and race is a minimum.

Actual experiment shows a relatively greater friction loss in the single-row bearing due to the character of the pressure area in the outer race.

It will be understood that a ball may spin as well as roll. In this case the bearings experimented upon had the following dimensions: Bore, 50 mm.; outside diameter, 110 mm.; width, 27 mm.; and rotational speed 1,000 r.p.m. The spinning effect was one revolution about the spinning axis to approximately 600 revolutions in the normal direction. This can be regarded with reason as an advantage, as it enables the small deformations in the material of the ball to be gradually distributed over its surface. In the case of the single-row bearing the spinning effect is nil.

A considerable amount of discussion has taken place on the relative thrust capacities of journal ball-bearings, and in the early days the ball bearing manufacturer wisely deprecated the practice altogether. He was aware that the bearing could take a proportion of axial load, but was conservative as to the amount and the life of the bearing under these conditions. Many failures resulted from users being too optimistic, but under the stress of increasing demand for still more efficient bearings the maker has been compelled to state precisely what the ordinary journal ball bearing may be expected to do as a double-purpose unit.

In the case of the single-row bearing, the carrying of axial load is due to compression in the balls, which permits of lateral movement of balls and inner race relatively to the outer one, and thereby transmitting the load across the balls at a certain angle. As for the double-row self-aligning bearing, the imposition of a radial load involves an axial one by virtue of the geometrical construction, and it is by simple virtue of the same principle that the bearing can take a certain axial load without any difficulty. The question is entirely one of deciding exactly what is the safe proportion.

The recommendation of the makers is the true index to their confidence in the bearing, which may be expected to take about 25 per cent. of its listed radial capacity as thrust load in continuous running. In the double-row self-aligning bearing the thrust capacity varies with the cone angle, and in the case of the lightest narrow types the coefficient is about one-ninth. It increases with increasing width of bearing until in the widest type, designed specially for maximum-thrust load, the coefficient is one-third.

The principal conditions which the bearing must fulfil are as follows:—

1. Capacity for taking combined radial and thrust load.
2. A self-contained unit having no loose parts, and without the necessity for any adjustment.
3. High fatigue limit to give resulting long life.
4. Lowest possible friction.
5. Absence of vibration.

It will be seen from the review that both single and double-row constructions fulfil these requirements to a considerable degree, although with reference to the last two dealing with friction loss and absence of vibration the double-row construction is superior. It is still a frequent experience of the ball-bearing manufacturer to find the engineer prepared to apply ball bearings where the loads are steady, but if shock is encountered, say, for example, in a tram axle-box, a tram motor, hot saw, or a wood-working spindle, there is some unknown force operating which he feels cannot be handled. He has an idea that the point contact makes it impossible for this force to be absorbed successfully, but he should understand that the majority of such forces are convertible in a more or less accurate degree into equivalent radial load.

The thrust capacity of the journal bearing has already been dealt with, and where thrust load is present in combination with radial duty it is simply a case of using a suitable factor to convert the thrust into an equivalent radial load. In other words, if there is a thrust of 200 lb. in combination with a radial load of 1,000 lb., this means an equivalent radial load of 1,600 lb. for certain designs, and the bearing is selected accordingly. If, on the other hand, there is shock present, this in the first place may be taken to represent 1·5 to 2 times the static load. Should the duty be only for intermittent periods, this factor might be quite sufficient in itself, but if the bearing is running continuously the resulting figure should probably be multiplied by two at least, before referring to the suppliers' list of ball-bearing rated loads.

One of the most important features to bring to his notice is the fatigue element, that is to say, whether the bearing will run continuously 24 hours per day, or 8 hours per day, or perhaps an occasional revolution. Bearings for electrical machinery, for example, are frequently under full load night and day, in which case fatigue effect is a maximum, whereas a bearing applied to a railway turntable may have only an occasional revolution in the hour. The margin of safety to be allowed by the ball-bearing manufacturer is considerably affected by this.

The best lubricant for ball bearings, which acts mainly as a preservative, is a good quality mineral oil, which might have an analysis as follows:—

Ball-Bearing Oil.	Maximum.
Free mineral acid	Nil.
Free alkali	Trace.
Sulphur	0·03 per cent.
Ash	Trace.
Rosin	Nil.
Salt	Nil.

Flash point (Pensky-Marten's apparatus), 300 deg. F. (150 deg. C.).

Heat test (15 minutes at flash point), slight darkening but no sediment.

Oil should be pure mineral, without gum, and should not become sticky.

Viscosity, 170–250 Redwood seconds (6–9 Engler degrees).

Where grease is used, however, the main point to be observed is that it does not contain free acid or alkali. A suitable analysis would be:—

Grease.	Maximum.
Free mineral acid	Nil.
Free alkali	Trace.
Sulphur	0·03 per cent.
Rosin	Nil.
Salt	Nil.
Neutral saponifiable oil	1·00 per cent.
Ash	1·8 per cent.
Moisture	2·0 per cent.
Abrasive particles (sand, &c.) ...	Nil.
Melting-point 180 deg. to 208 deg. F. (82 deg. to 98 deg. C.).	

Where the bearing is working under high temperature conditions, the flash-point of the mineral oil will require special attention. The oil should be subjected to a temperature of say 50 deg. C. above that at which the bearing is working, so as to remove inflammable particles.

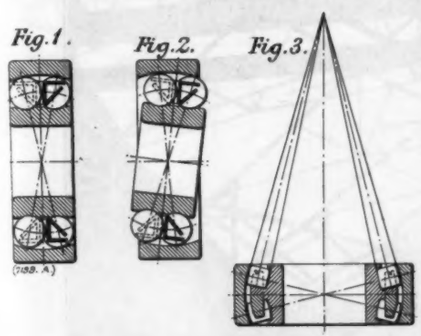
In the case of transmission work a housing is simply packed with grease, and may be left for three or six months without further attention. With wood-working machinery and such applications involving high rotational speeds, rather more care is necessary to prevent heat being generated in the housing due to churning of the lubricant. These are matters, however, which are readily settled by reference to the ball-bearing manufacturer.

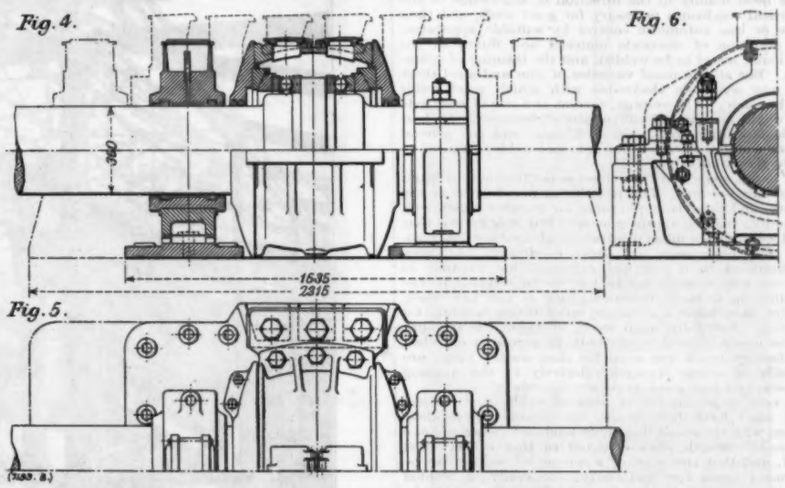
Commonly it will be found that the engineer has a predilection for a roller bearing on account of its high radial capacity, but as a matter of fact, it might be stated that the majority of applications are more amenable to the adoption of a ball bearing. There are certain cases, however, where an exceptional heavy radial load makes too severe a demand upon the ball bearing, especially if a long life is to be guaranteed in face of high fatigue conditions. The necessity of this became evident as the application of ball bearings to rolling-stock developed.

One interesting design is based on the double-row self-aligning bearing, the balls in this case being replaced by conical-shaped rollers, as illustrated in Fig. 3.

This bearing is of particular interest on account of the special care taken to ensure absolute roller guidance. The cage is really more a separator, as the guidance is accomplished by causing the rollers to bear against shoulders on the inner race. In some cases where a similar method is adopted, the contact at the shoulder is a point. In this case, however, the ends of the rollers as well as the ends of the shoulders on the inner race are ground to the same curvature, the centre of which lies on the main axis of the bearing, extended. In consequence of this a definite area is provided instead of a point, and the reactions of the load through the roller are so arranged that a small axial component keeps the roller lightly, but sufficiently, pressed against the shoulder during rotation. This is just sufficient to provide the adequate guidance necessary, and the bearing in this respect represents a radical departure from all previous practice.

Figs. 4, 5 and 6 illustrate the shaft and bearings for a 4,000-ton vessel equipped with 1,350-h.p. engine for a speed of 12 knots. The bearing is mounted on a flange which has been forged in one piece with the shaft, which is a great advantage in mounting. The bearing design shows the reduction in length achieved. Similar applications of the principle has also been made on various motor ships of 5,000 tons each equipped with three 500-h.p. engines. Other applications are to motor-driven turbine steamers. These vessels are each of about 3,000 tons, and every satisfaction has been obtained with this class of work generally over several years' running.





* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, December 13, 1921.

HELIUM FROM NATURAL GAS.—The installing of equipment in the cryogenic or low-temperature laboratory at Washington, D.C., is practically completed, and liquid air in quantity is now being produced. The primary object of this laboratory is to investigate gases and liquids at low temperatures, with special reference to the separation of helium from natural gas. The scientific data obtained will be applied in the helium plants to obtain more efficient operation and to reduce cost of production. Work is being carried on along two lines, vapour-pressure work in connection with ternary mixtures and investigations relative to the purification of helium by charcoal at low temperatures. The experimental helium plant at Petrolia, Tex., using the Jeffries-Norton process, was in operation during last year at various times, and helium was produced for short periods, yielding a product as high as 49 per cent. helium. The plant, however, was not developed into an actual operating unit, and on account of Congress greatly reducing the funds for helium work during 1921 and 1922, it was decided to discontinue operations at Petrolia in July and to place the plant in a stand-by condition until further fundamental data required for efficient operation could be obtained through work on a smaller scale. In the meanwhile the larger part of the funds appropriated for helium work will be used for the production of helium in the plant erected by the Navy Department at Fort Worth, Tex., which is now in regular operation producing helium.

ELECTRIC ARC WELDING IN STEEL STRUCTURES.*

By JAMES CALDWELL, M.Inst.C.E.

ELECTRIC arc welding or autogenous soldering of ferrous metals with the aid of electrodes of iron or steel has found a rapidly-extending field of application during the last few years. Viewed at first with some suspicion in respect to the reliability of the strength of the joints so made, this extension of use has naturally followed upon the efforts of the practitioners to detect and eliminate the causes of defective work, and the experience of users that welds made by good operators under proper conditions are in fact reliable in use.

Electric arc welding was tried at first for repair operations, generally because it was evidently quicker and cheaper than any other method, or because there was no other method. If it failed no one was much the worse, if it succeeded time and money were saved. This was especially the case in respect to the repair of ships and machinery during the war, when time-saving was all important, and replacement parts hard to come by.

The generally good results obtained showed that the process was more reliable than some of the users dared to hope. Less satisfactory results threw light upon causes of weakness, and led to efficient measures for their prevention. Advance in the art has, therefore, been both practical and experimental. Tests in the proving-house have supplemented the tests of use, and it is now possible to give reliable figures for the strength of welds in the terms used for the specification of the strengths of materials.

The advances in technique which have led to this result have been mainly in the direction of knowledge of the electrical conditions necessary for good work, and their more or less automatic control by suitable apparatus, the adoption of electrode material and fluxes to the particular metal to be welded, and the training of operators. For all the usual varieties of iron and steel there are now available electrodes with which good welds can be made. The voltage, current and size of electrode for welds in material of various dimensions, the best methods of preparation in each case, and the general procedure have been worked out, and welders trained to apply this knowledge.

It is not suggested that there is nothing left to learn about arc welding. The practice is in advance of the theory, and there is ample room for research which will, no doubt, suggest improvements. But it is known that good welds can be made if certain conditions are observed, and the observance of these conditions has been standardised to a practical degree. This advance in practice has recently led to the use of welding in the building up of steel structures, such as roof principals, girders, stanchions and masts, substituting welding for riveting. Naturally, such work, in which the strength of the joints is vital, could only be ventured on when satisfactory proof was available that welded joints are actually of ample strength relatively to the working stresses, and that good welds are the rule.

A very large number of tests of welds in structural mild steel have been made by various independent bodies, with the result that these welds are shown to have a tensile strength sensibly equal to that of the steel itself, and that the work of a competent welder can be depended upon for uniformity. Generally, a welded test-piece tested to breaking under tension breaks outside the weld itself, *i.e.*, the weld metal is slightly stronger in tension than the mild steel welded. This does not mean—as is sometimes suggested—that the original metal is weakened by the heating adjacent to the weld, as the breaking stress is as high as that of an unwelded specimen. The weld metal itself is somewhat less ductile than the original metal, and has less elongation and reduction of area for the same breaking stress. This lower ductility is also shown under bending tests, the weld metal begins to fail at a smaller curvature or angle of bending than mild steel. Alternating and impact tests give good figures, and the elastic modulus of the weld metal is sensibly the same as that of mild steel.

Given these factors, it is therefore, possible to design steel structures having welded joints with as much confidence as with riveted joints. It may even be suggested that the strength of welded joints is more determinable than that of riveted joints. There is also a considerable saving due to the extra strength arising from the elimination of bolt and rivet holes. This enables various sections to be made lighter by about 20 per cent.

In similar structures the cost of arc welding is decidedly lower than the cost of riveting, and the time taken in erection is also less. The operations are fewer and the whole work simpler. The transport of the material to the place of erection is also facilitated. The members of a roof truss or girder can be cut to length by the steel works, sent to the site bundled or loose, as may be convenient, and laid out on the floor to proper marks or to a simple jig. The ends of the bars have to be chamfered, veed or cleaned before laying out, and are then ready for the welder. The actual welding takes less time than riveting and fewer men. If an electric supply is available on the site, the necessary apparatus for its control and distribution to the welders is simple and not bulky, rather simpler if the supply is alternating than if continuous. If there is no electric supply a portable welding set, consisting of a petrol or oil engine and dynamo has to be used. These sets are mounted on trucks so that they are readily shifted to follow the work.

There is some saving in weight of the completed work, since it is generally possible to dispense with the gussets and plates required in riveted trusses. There is also less chance of error in assembling, as the welding is done whilst the members are lying in correct positions in the jig.

Some examples of work done will perhaps be of more interest than these general considerations.

Roof trusses of 14-ft. 6-in. span have been used for the Horse Show stabling at Olympia since 1920. The order was received on April 27, the iron was available in London, it was cut to lengths, assembled in a jig and welded up into trusses. It was found that two welders and four labourers could turn out 10 of these trusses per day. The work included the welding on of clips for wooden purlins, and seating plates on the top of the I-stanchions. The whole of the ironwork—68 trusses and 130 stanchions—was ready for erection on site on May 5. The roof covered an area of about 9,000 sq. ft.

A bigger example is a workshop roof in Brooklyn made up of bowstring lattice trusses of the Polonceau type, with a span of 40 ft. The upper and lower members are of T's 5 in. by 4 in. by $\frac{7}{16}$ in., and the lattice, bars of angles of 3 in. by 2 in. by $\frac{1}{4}$ in. These were welded up without gusset plates and on erection welded to seating plates on the supporting stanchions. Purlins of 10-in. channel iron are welded to the upper members. Each truss had to carry 800 sq. ft. of roofing weighing 40 lb. per square foot. They were tested by a dead-weight load of three times this amount, *i.e.*, 120 lb. per square foot, or 48 short tons (42·8 English tons) per truss. This load was kept on for two days, and produced no permanent set whatever. This shows a greater rigidity than found in riveted structures of similar character, which always show a little deformation due to slip, &c., in the riveted joints after a heavy test load. This slip deflection under test is not calculable, whereas the welded structure will not show permanent set until the elastic limit of some of the members is exceeded. In this building brackets were welded to the stanchions to carry a 5-ton travelling crane. The whole structure was specially tested by the New York City Building Department, the plans having been passed subject to the tests being satisfactory, in view of the novelty of the method. The official report lays stress on the superior rigidity shown as compared with similar riveted structures.

Perhaps the most interesting work so far completed in this country is that for an extension of a foundry belonging to Messrs. Cowlishaw, Walker and Co. (1920), Limited, at Stoke-on-Trent.* This is shown in Fig. 1 annexed. This roof is not symmetrical about its supports. There is on one side an extension or lean-to roof, of which the outer edge rests on a retaining wall inclined to the axis of the main roof and on the other an extension covering the railway siding. The lean-to rafters, are, therefore, of varying length. The stanchions have to carry the runway for a 20-ton overhead crane.

A railway siding already referred to had to be bridged by a girder of 50 ft. span, which carries the crane runway, and above it a lighter girder supporting the intervening roof principals. The stanchions are of box form built up of stock sections. The whole of this work, stanchions, roof principals, girders, crane runway and lean-to rafters has been put together by arc welding. This process facilitates design by utilising stock structural shapes, which would require special fittings to be brought into a riveted structure, or could not be brought in without difficult and expensive work. Four stanchions are alike. Each one is made up of one 12-in. by 3½-in. channel 23 ft. long, one 12-in. by 5-in. H-joist 20 ft. long, and one 8 in. by 5-in. H-joist 29 ft. 6½ in. long. The 8-in. by 5-in. joist is welded by the edges of one flange to the inside of the web of the 12-in. by 5-in. channel, and the channel and 12-in. by 5-in. joist are made into a box by five stiffening plates welded to the outsides of the flanges of those members. The whole stanchion is then in plan a rectangle of 24 in. by 12 in. The stiffening plates at the lower end are flared out to a length of 36 in. with 4-in. by 4-in. angles welded to bottom edges, and a base plate 36 in. by 28 in. welded to the angles forming the base to meet the footings. The stiffeners at the upper end are flared out on the inside only, with a cap plate welded across them and the upper end of the 12-in. by 5-in. joist, to afford a seating for a 24-in. by 6-in. joist which spans the stanchions and carries a 15-in. by 4-in. channel on the centre line of which the crane rail is welded. The long 8-in. by 5-in. joists form the roof supports.

The channel, which it will be seen extends a little above the crane rail level, has 4-in. by 4-in. angles welded to each flange, which extend about 4 in. on to the upper side of the web of the 15-in. by 4-in. channels, to which they are welded, thus strutting the crane rail bearer to the stanchion channels.

Another stanchion has to carry the outer end of the girders bridging the 50-ft. opening for the railway siding. It is made up with some necessary modifications in a similar way to the four just described. A sixth stanchion carries on the outside, *i.e.*, on the web of the channel, two brackets, the upper one of 12-in. by 5-in. joist supporting the runway of a 5-ton travelling crane, and the lower one, a 9-in. by 3-in. channel on edge, both belonging to the extension of bay.

FIG. 1. FOUNDRY BUILDING FOR MESSRS. COWLISHAW, WALKER AND CO. (1920), LIMITED, STOKE-ON-TRENT.

The girder spanning the gap and carrying the crane rail is a box lattice girder, 4 ft. 1½ in. deep by 1 ft. 8 in. wide. The top and bottom booms are each made up of two 9-in. by 3½-in. channels on edge with the webs outside, and cover plates overlapping the channels 3 in. on each side. The diagonal struts are angles of 3 in., 4 in. and 5 in. by 3 in. by ½ in., and the verticals are 12-in. by 3½-in. channels, fitted between the upper and lower booms and welded to the flanges thereof. The only drilling in this girder was for anchor bolts at the abutments, one of which is on the wall.

It will be appreciated that these stanchions and the girder are stiff, strong and light, that they are made up of standard sections with no special gusset plates or other fittings. They could hardly be put together by riveting, or rather if riveting had been used they would have been differently designed.

The roof principals are of quite usual design. Attention may be drawn to the louvre frame, as it shows how simply such a structure can be built up by welding. The supports for the louvre slate are short pieces of angle iron welded to the uprights by their edges. It will be noted that gusset plates are used in this design, affording a large section of weld at each joint, but these gussets are considerably smaller and simpler than would be required for riveted joints.

The intermediate principals are carried on H-joists bridging the stanchions and supported by angle brackets welded to them. The side rafters for the lean-to and the extension covering the railway siding are of 12-in. by 5-in. H-joints. They were put in place after the main principals were erected and welded to their supports and secured to the principals by welding to a plate welded in between the members of the principal and fitting the web of the side rafters between the flanges.

* Abstract of a paper read before the South Wales Branch of the Institution of Mechanical Engineers, at Swansea, on January 10, 1922.

* Drawings of this work were published in ENGINEERING, vol. cxi, page 323.

This welding was quite easily done in place. Each principal was assembled by laying the bars in a jig, welding all the joints on the upper face, then turning over and welding the joints on the other face, much simpler handling than would have been required for riveting.

Another example of building construction is a steel building for Messrs. The Galvanising Equipment Company, Limited, at Tottenham. This building is a skeleton steel structure, the walls and partitions formed by hollow blocks which carry only their own weight. The width is 70 ft. 3 in., made up of a main truss span of 40 ft. 3 in. and two wing or lean-to trusses of 15 ft. span each. The length is 200 ft. There are 16 main, 32 wing and two gable trusses. The height from floor to roof ridge is 27 ft. The weight of the roof is carried on H-section stanchions, the side or wing stanchions are 9 ft. 6 in. high, the inner stanchions 14 ft. 6 in. high. These stanchions were cut to length, the base and cap plates welded on at the Welded Construction, Limited, works, while the ground was being cleared and the foundations prepared. The stanchions were placed and bedded in concrete, and the stretcher bars welded to them. The trusses were made up in halves at the Construction Company's works, taken to the job and welded up on the site. There was at the time no clear space at Tottenham for laying out the truss members, and time was saved. The half trusses were made up in jigs. The whole work was erected between August and October, 1920, nine weeks from the date of the first deliveries of stanchions. Fig. 2 shows the completed skeleton on October 8. The roof has been found strong enough to carry an overhead runway, which it was originally proposed to support separately. Fig. 3 shows the general arrangement of the steelwork.

Another application of arc welding is in the construction of poles and masts of the lattice type. There is at present a good demand for these lattice masts for the support of electric transmission lines and wireless aerials. An example is shown in Fig. 4, which represents one of 500 transmission line posts recently constructed in Belgium. These posts are 72 ft. long overall, of which 5 ft. is embedded. They are to carry two three-phase lines and a guard wire, altogether seven wires, on spans of 525 ft. The stress due to the pull of the wires with a maximum wind blowing across the line is calculated to amount to about 1,350 lb. horizontal pull at the top of the post.

They are of square section, 40 in. by 40 in. at the ground level tapering to 19 in. by 19 in. at the top. The longitudinals at the corners are of T-iron, 3½ in. by 3½ in. by ½ in., in the lower section, and 2 in. by 2 in. by ¼ in. in the upper. The lattice bars are also of T-iron, 1¼ in. by 1¼ in. by ¼ in., and 1½ in. by 1½ in. by ¼ in., respectively. For convenience of transport the upper and lower sections are arranged with a bolted joint between them. A sample post was placed horizontally with the butt end embedded in masonry, and loaded at the point corresponding to the centre of pull when erected. At the prescribed maximum working load a deflection of 6½ in. was measured, 3 ft. on the butt side of the load and at double this load the deflection was 9½ in. There was no measurable permanent set. These posts weigh 10 per cent. less than those riveted in the usual way. Two welders can complete one in 9 hours' work, using arc weld the flanges to steam pipes, with quite satisfactory results.

A gas holder recently placed in commission at Johannesburg was constructed entirely by means of the Alloy Welding Process of electric arc welding. The water-jackets are of ⅜-in. plates cut to size by oxy-acetylene blowpipes. The capacity of the gas-holder is 8,000 cub. ft.; it is 25 ft. in diameter, 14 ft. high and of ¼-in. thickness of plate. No riveting was used in the manufacture and erection, including the joining of the plates, also the attachment of 90 lugs, 9 flanges and 54 pipe sockets. There are six inner jackets (two spare), which were tested for tightness with paraffin for one hour, in the presence of Mr. Price, consulting engineer to the Rand Mines.

In adopting a new process of this kind for any sort of structure the designer must have reliable figures for the strength of the joint, just as he must have reliable figures for the strength of the main material. A large number of tests have been made by the Admiralty, Lloyd's and by other independent testing establishments. These tests have been made mainly on welds in mild steel of ship and structural quality. A very full account of such tests was given in a paper contributed by Sir W. S. Abell to the Institution of Civil Engineers in 1919. These tests go beyond the investigation of ultimate strength, as they were devised to throw light on the physical properties of the welding and welded material and its ability to resist the alternating stresses to which ships are liable.

A summary of test results to date will give some idea of the extent to which welds in steel structures can be relied upon. It should be premised that these are for mild steel of the usual structural qualities, and that the welds were made with flux-coated electrodes by various makers, intended for that material.

Tensile Strength: (*a*) *Plain Butt Joints.*—In the majority of welded test-pieces the fracture takes place in the original material, not in the weld, but as the weld metal is somewhat less ductile than the original material this may be due to a greater contraction of area in the original material. The results show that for pure tensile stresses arc welds can be relied upon as equal to the steel itself.

(*b*) *Lap Joints.*—These may be made with a full fillet on each side or a full fillet on one side and a single run on the other just to close the landing edge against the entry of moisture. Such joints when tested in tension experience a certain amount of bending as the test-piece tends to take up a straight line. The bending stress is most severe at the end of the overlaps. Double-filleted joints generally break across the solid plate at the edge of one of the fillets at a stress of from 70 per cent. to 85 per cent. of the breaking stress of the plain plate. Single filleted lap joints generally break in two stages about 45 B.o.T. units and 425 ft. of No. 10 electrodes. For the construction of transmission lines where transport is difficult it may be well worth while to build up such posts with portable welding plant at convenient points on the line.

The very tall masts required for wireless aerials have to be built up in place. The work can be done rapidly and cheaply by welding as the material can be cut out to lengths for easy transport, and the welding done from transformers hoisted to the working level. The individual pieces can be kept down to a convenient weight for lifting, and in other ways it seems that welding offers great possibilities of reducing the cost and erection time of such structures.

Another application which has not been made, but is under consideration for some specific cases, is that of the construction of large diameter pipe lines for hydraulic power installations. Whilst the process had not been used so far as is known for such pipe lines, there are some steam pipe lines of considerable length which have all joints welded. One of these in the United States is 400 yards in length, connecting two power houses. It is 12 in. in diameter, carries steam at 200 lb. per square inch, and the only flanges in the length are at expansion joints. It is a long-established practice to

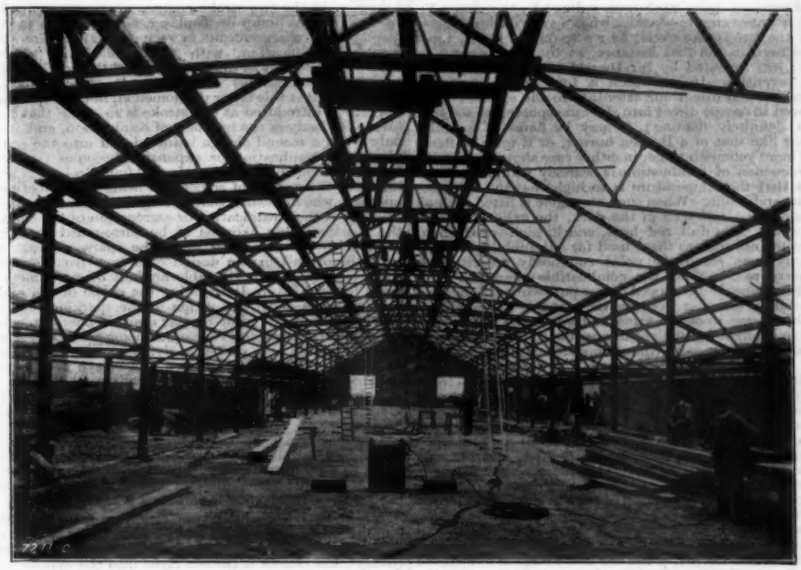
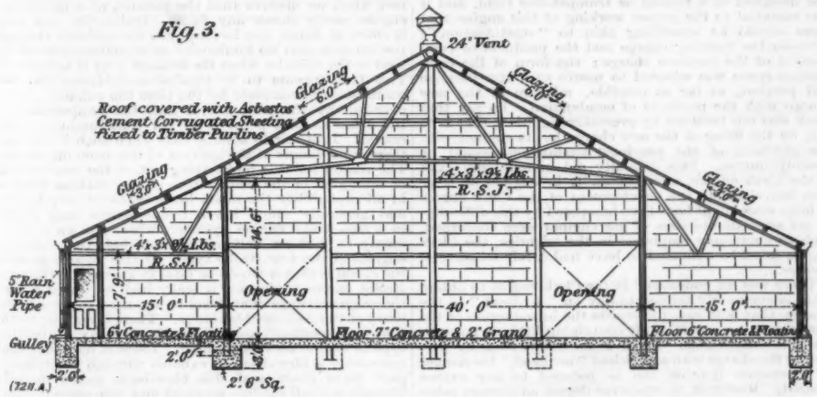


FIG. 2. STEEL BUILDING FOR THE GALVANISING EQUIPMENT COMPANY, LIMITED, TOTTENHAM.



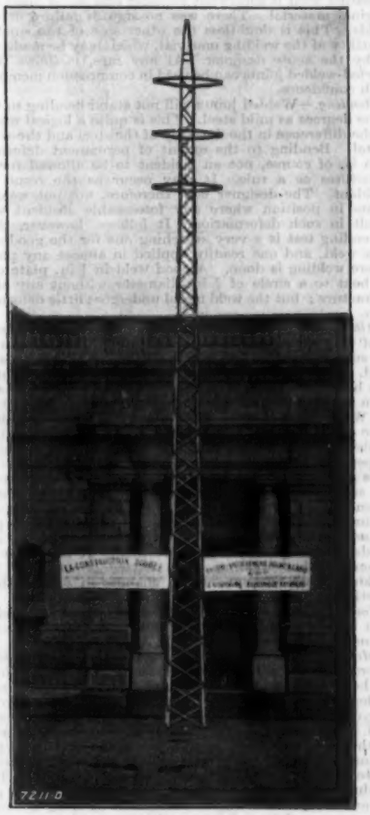


FIG. 4. 72-FT. MAST OF LATTICE WORK.

first the closing run fails, after which the full fillet yields.

Elongation.—As before stated, the weld metal is less ductile than the original mild steel, and necessarily the reduction of area is also less. The welded material breaks without much flow of the metal. The elongation in a transversely welded test-piece may be only about 8 per cent., and the reduction of area about the same percentage of the original cross-section, against an elongation of about 30 per cent. and a reduction of area of 40 per cent. to 50 per cent. for plain pieces. Such low elongation and reduction of area would be considered indicative of brittleness in structural steel and would justify its rejection. It has not the same meaning in welded joints.

Crushing Strength.—This item is not perhaps of much importance in structural designs, but it may have to be reckoned with in some cases, *e.g.*, where it is required to make up masts, &c., with joints in the vertical members. Professor Sir W. S. Abell gives some crushing tests in the paper mentioned, from which it would appear that a scarfed weld is somewhat stronger and stiffer than the original material. There was no sign of failure of the welds. This is doubtless the other side of the smaller ductility of the welding material, which may be made use of by the acute designer. At any rate, it shows that scarfed-welded joints can be used in compression members with confidence.

Bending.—Welded joints will not stand bending to the same degrees as mild steel. This is quite a logical result of the difference in the ductility of the steel and the weld metal. Bending to the extent of permanent deformation is, of course, not an incident to be allowed for in structures as a rule. It may occur as the result of accident. The designer will, therefore, not put welded joints in position where any foreseeable accident will result in such deformation. It follows, however, that a bending test is a very searching one for the goodness of a weld, and one readily applied in almost any place where welding is done. A good weld in ¾-in. plate can be bent to a circle of 1½ in. diameter without any sign of fracture; but the weld metal undergoes little deformation.

Alternating Stresses.—Endurance of alternating stresses is of very great importance, since all sorts of structures are subject to vibration and variations or alternations of load. Tests which give such alternation in a way which can be defined and compared with working stresses have been made in various ways. With a modified Wohler test Sir W. S. Abell showed that butt welds have an endurance of about 70 per cent. of that of the unjointed plates, whilst lap welds and riveted laps come out equal at about 60 per cent. of the endurance of the plain unjointed pieces. It is obvious that lap joints, whether welded or riveted, are subjected to a greater concentration of stress for a given extent of bending. Lloyd's Register specify an endurance of 5,000,000 reversals of a stress of 6 tons per square inch. This specification is easily met by arc welds and frequently much exceeded. It may also be remarked that welding offers better opportunity for making joints without sudden changes in section than riveting.

Impact Tests.—Lloyd's tests dispose of any suspicion that the comparatively low ductility of the weld metal connotes brittleness.

Modulus of Elasticity.—These figures are of considerable interest for fundamental calculations. They are obtained in the usual way by tests on specimens made up entirely of deposited welding metal. In one case of tests made by Lloyd's Committee, the specimens were strips 12 in. long, 1 in. by ¾ in. cross-section, machined to size. The stress at the yield point was 19 tons per square inch, and the ultimate strength 29·6 tons per square inch, agreeing quite well with the tests made on welded joints. The modulus of elasticity of this sample was 12,900 tons per square inch, which will be recognised as lying between the average figures for wrought iron and mild steel, other tests having given rather higher figures.

Elastic Limit.—Below the elastic limit of the welded material the relation between stress and extension is practically equal to that of unwelded material. Beyond this point, as above indicated, the extension and reduction of area is less than that of mild steel, or the ductility is lower, also the elastic limit appears to be slightly higher.

From these particulars it will be seen that the designer can reckon upon definite and satisfactory strength qualities in arc-welded joints. They are probably more definite than the qualities of riveted joints, certainly so in regard to rigidity of the structure, which is often important. Further, it is generally easy to provide welding surfaces giving large margins of safety over the bare section of the welded members, much simpler than the provision of gussets, palms and similar extensions necessary to permit of secure riveting.

The facility which welding affords for making up compound members from stock sections is well illustrated by some of the examples given, and will, no doubt, be developed by clever designers so soon as they realise the reliability of the process, and the saving in time and cost which result from its use.

"WILLING'S PRESS GUIDE."—This guide for 1922, the forty-ninth annual issue, gives the titles, the year when first published, period of publication, price and address of all newspapers and periodicals of the United Kingdom, arranged alphabetically under titles; the same papers and periodicals are also classified according to the interests, professions, trades, &c. they deal with. Other chapters enumerate the metropolitan newspapers, the metropolitan and suburban local publications, those of the counties and provincial towns, the titular changes and amalgamations, Colonial and foreign journals, &c. The book is published at the price of 2*s.* 6*d.*, by Messrs. James Willing, Limited, 30, King-street, Covent Garden, W.C. 2.

THE TWO-STROKE MOTOR CAR ENGINE.

*An Investigation of Certain Aspects of the Two-Stroke Engine for Automobile Vehicles.**

By F. W. LANCHESTER (Past-President) and R. H. PEARSALL (Member).

PART I.

THE object of the present paper is the investigation of the principal factors controlling the performance of internal-combustion engines functioning on the two-stroke cycle, more especially such engines in their smaller sizes and simplest form adapted to work at comparatively high revolution speeds. Broadly, the conditions covered are those which may be said to obtain in engines suitable for automobile propulsion.

From a thermodynamic standpoint, as concerns the cycle of operations, there is no difference between the two-stroke cycle and the four-stroke cycle types. In both the working fluid is compressed from a volume V_1 to a volume V_2, ignition then takes place and the working fluid expands doing work from volume V_2 to volume V_1.

It is interesting to consider what a very daring suggestion the two-stroke cycle, as we to-day know it, must have been in the first instance, at the time when this cycle was invented by Sir Dugald Clerk somewhere in the 'seventies. If we watch a four-stroke engine in operation and direct our attention to the exhaust when allowed to escape direct into the atmosphere, we see that it is definitely flaming; it may be flame of a bluish colour like that of a Bunsen burner, or it may be flame of a more yellowish tinge, in either case showing that the phenomenon of combustion is scarcely complete, or at least that the temperature is so high that the hot gases are incandescent. When such an engine is fitted with an exhaust pipe and seen in the dark, the exhaust pipe is commonly of a dull red heat, and in high-speed, high-duty engines such as those used for automobile purposes it may even reach the point commonly described as "cherry red." Now, the combustible charge in two-stroke engines is introduced at one port while the exhaust is actually escaping from another, and if the condition of the charge were the same as that in the four-stroke engine it might be thought impossible that a new charge could be introduced without immediately catching fire and being prematurely burnt. This view receives additional support from the fact that in the four-stroke engine, if the mixture is somewhat weaker than it should be, not only is the flame still alive when the exhaust port opens, but it is still alive even after the full return stroke, so much so that the incoming charge in a four-stroke engine is sometimes prematurely ignited, and popping back into the induction pipe takes place.

Briefly treating the matter historically, Fig. 1 is a diagrammatic representation of the Clerk engine. In this engine the exhaust is allowed to escape by ports distributed round the periphery of the cylinder adapted to be over-run when the crank has traversed about 120 deg. from the ignition point, and the new charge is introduced simultaneously through a lift valve at the back end of the combustion space from an independent displacer or pump. It will be seen in the diagram that the combustion space was designed of a conical or trumpet-like form, and it was essential to the proper working of this engine that there should be something akin to "stratification"† between the entering charge and the products of combustion of the previous charge; the form of the combustion space was adapted to secure such stratification and prevent, as far as possible, mixture of the new charge with the products of combustion. To say that Clerk was not troubled by premature ignition, that is to say, by the firing of the new charge by its contact with the products of the previous combustion, would be entirely untrue. This difficulty did undoubtedly exist in the Clerk engine, more especially in engines of large size, but although the development of the Clerk engine to large sizes might have been hampered by this difficulty, so far as moderate sizes of gas engines were concerned, such as commonly employed in the 'eighties, the Clerk engine must be admitted to have had a fair measure of success.

There was an endeavour in the Clerk engine to obtain what is commonly termed to-day an "air-head" to the charge, that is to say, to precede the introduction of the new charge by a puff of air containing little or no combustible constituent. There is no doubt that by preceding the charge with a sufficient "air-head" the danger of premature ignition can be reduced to any extent desired. Moreover, to whatever degree admixture takes place between the incoming combustible charge and the products of combustion, there is liable to be loss of valuable unconsumed fuel through the exhaust ports, and here again the air-head to the charge may be used as a means of diminishing the loss. To realise this, let us consider the charge, that is to say, the air and the gas or air and petrol vapour, as constant in mean composition and quantity, then it is evident that the first part of the charge entering the cylinder will be the first to risk being blown out unconsumed through the exhaust; if, then, the first part of the charge be air only, and if the latter part of the charge contain the whole of the gas or petrol vapour, that is to say, if the gas or petrol be held back and entirely introduced during the latter part of the charge, any loss that takes place will be wholly air and higher fuel economy will result.

The question of stratification, when we compare the two-stroke cycle and the four-stroke cycle, is one of vital importance. It may be briefly expressed by saying that whereas in the two-stroke cycle we aim at stratification because it is essential to the performance of the charging cycle, in the four-stroke cycle we aim at the elimination of stratification because it is detrimental to the proper functioning of the working cycle. But the question immediately arises—if stratification is bad in a four-stroke engine from the point of view of the completeness of combustion, &c., is it not also bad in the two-stroke engine from the same standpoint? Probably it is, and under certain conditions undoubtedly it is, but we have to remember that although the stratification exists during the charging period, there may be very little stratification left by the time the ignition point is reached—the turbulence and stirring up of the charge is so great that, during the compression period (about a third of a revolution of the crank) what remaining stratification there may be is largely dissolved.

Both in the two-stroke cycle and in the four-stroke cycle the phenomenon of stratification is noticeable under governed conditions. Thus, when a four-stroke engine is running light under nearly closed throttle, the incoming charge is comparatively small and it does not in all cases fully admix with the residuaries. When this happens misfires or "hang-fires" are liable to occur. Likewise, in the two-stroke engine, when governing by throttle on the pump or displacer, the smallness of the displacement charge results in very poor admixture with serious stratification, with the result that misfires become so frequent as to be the order of the day, and the two-stroke engine (as it is termed) "four-strokes." The meaning of this latter phenomenon, of course, is that the charge introduced at one stroke is so small that it is lost in the body of the products of combustion, and it is only when a second charge is introduced into the same mass that combustion or expansion becomes possible. In the intermediate state before "four-stroking" sets in, there is a period of sometimes firing and sometimes missing, which means that the ignition depends upon whether in the stratification or segregation of the charge the sparking plug happens to be surrounded by inert gases or by live mixture when the spark passes. As evidence of this in the design of a two-stroke engine, there is always a considerable amount of experimental work to be done in determining the shape of the combustion space and the position of the sparking plug in order to obtain the most regular ignition possible under throttle conditions, the endeavour being made to secure that there shall be a pocket of live mixture at the point of ignition. In some cases two plugs have been fitted situated in different parts of the walls so that there is less chance of the ignition being missed owing to one or other of the sparks being drowned by products of combustion.

Thus, from a heat cycle standpoint, stratification is equally undesirable both in the four-stroke cycle and in the two stroke cycle, but it is necessary in the two-stroke cycle at the period of charging owing to the peculiarities of the charging method adopted.

It is not too clear why the two-stroke engine is so nearly immune from premature ignition, especially when, as in the Day engine, Fig. 2 (the parent of the form common to-day), the charge is thrown right into the cylinder on the heels of the escaping exhaust, and this at considerably less than half a revolution from the ignition point. There is some clue to the explanation of this surprising fact when we observe that the exhaust of a two-stroke engine rarely shows any flame. Ordinarily, not only is there no flame, but looking into the cylinder through the exhaust port no luminosity or incandescence can be seen in the cylinder when the exhaust port is uncovered. This fact appears to be conclusive evidence that the combustion is complete by the time the exhaust port is over-run by the piston, and that the temperature of the gases at that point is so low that luminosity has ceased. It is fair to assume that when such is the case there is no danger of the ignition of the incoming charge. The reason for this rapid dying out of the combustion, or falling-off of the temperature of the working fluid, is in all probability the much lower combustion intensity and generally much lower temperatures that obtain in a two-stroke engine cylinder, where the ηp is commonly only about half or less than half that usual in engines of the four-stroke type. If this view is correct, the moral is that it would be fatal to attempt in the two-stroke engine to develop a really high ηp unless a very thorough scavenge or air-head be arranged to precede the entry of the combustible charge. There is another factor that may, perhaps, account for the capacity of the Day type of engine for fast running. There is no doubt that commonly a blow-back of exhaust through the transfer port takes place, and this blow-back passes initially through a small slit-like aperture and undergoes cooling. When in turn the pressure in the cylinder has fallen sufficiently and the new charge comes in through the transfer port, it is preceded by a head of cooled exhaust gases, and it is possible that this cool exhaust-gas head acts as a protection to it in preventing premature ignition.

Although the air-head is thus by no means necessary (as proved by experience) in the present paper considerable evidence is given as tending to establish the value of an air-head if suitably provided, but it cannot be said that the advantages demonstrated are sufficient to make out more than a *prima facie* case for the air-head as against the ordinary simple three-port engine. One of the two great advantages of the two-stroke engine is its extreme simplicity, and consequently any feature that tends to depart from this simplicity must be regarded with suspicion and jealously scrutinised before it is admitted as a desirable feature. As a measure of this simplicity, it is legitimate to regard the single-cylinder two-stroke engine as equivalent to a two-cylinder four-stroke engine.

One of the items which the authors of the present paper set out to determine was whether the relative inefficiency of the two-stroke engine is really necessary and essential, whether, in fact, by improvements in design, or detail, or in method, part or whole of the loss of fuel could be

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* Paper read before the Institution of Automobile Engineers, January 12, 1922.

† The converse of admixture.

obviated. It cannot be said that this question has been fully answered—in some respects the results have been disappointing. The designer of the two-stroke engine is between the devil and the deep sea—either his ηp has to be kept low, or alternatively there is an outrageous loss of unburnt charge through the exhaust port. Even a carefully thought-out provision in the way of an "air-head" has not given the results hoped for, and the authors have come to the conclusion that, in the three-port type of engine at least, a fundamental difficulty is encountered in endeavouring to clear or sweep out the residuary contents of the cylinder beyond a certain point. This difficulty, which will be referred to more fully in the main part of the paper, appears to consist in the creation of a vortex within the cylinder, the core of which consists of residuaries, and this core cannot be tapped off by any convenient or available means. In all probability this difficulty did not arise in the Clerk type of engine to which reference has already been made. The theory suggests that a greater displacement efficiency might be obtained if the charge could be introduced tangentially and the products of combustion drawn off centrally so that a vortex is formed of which the axis is the cylinder axis and in which the central core passes out through a concentric exhaust port in the cylinder head. This suggestion, however, would involve a mechanically-operated exhaust valve, and we are at once losing some of the simplicity which, as before stated, is the one great charm of the two-stroke cycle.

It would appear from the experimental work which the authors have conducted that the point at which the heavy exhaust port loss begins is quite definitely marked, in a well-designed engine at an ηp value of about 35 lb. per square inch. This is little more than one-third of the ηp in a modern four-stroke engine. The most promising course, therefore, appears to be to design the engine for comparatively low ηp values, and in fixing the size of an engine for any particular duty to regard $\eta p = 35$ as being the nominal full-load condition. If we compare two cars then, one equipped with a four-stroke engine and the other with a two-stroke engine, we have petrol economy, performance for performance, which in the two-stroke is little inferior to that of the four-stroke, and the said two-stroke engine has one advantage over the four-stroke, namely, a capacity for taking an overload.

In conclusion, reference may be made to a few of the minor disabilities peculiar to the two-stroke engine. The over-run ports in the cylinder tend to interfere with the lubrication and result in a loss of lubricating oil, incidentally fouling the exhaust and rendering the engine liable to smoke. Associated with this is the gumming up of piston rings where exposed to direct heat in the exhaust port. A further point, a frequent source of trouble, is that of a leakage and consequent fouling of a charge in the crank-case; any blow-through from the piston not only involves a direct loss of power as in the four-stroke engine, but also results in fouling the new charge, so involving a double loss of power. Leakage through the engine journals or otherwise into or from the crank-case also may result in vitiating the mixture by dilution with air, and in a direct loss of petrol vapour into the atmosphere. These involve care in design, but are not in any sense insurmountable.

PART II.

IDEAL PERFORMANCE.

Symbols.

- P = Pressure, lb. per square inch.
- V = Volume of 1 lb. of charge.
- T = Absolute temperature Fahrenheit.
- S_v = Specific heat at constant volume.
- S_p = Specific heat at constant pressure.
- $\gamma = S_p/S_v$ = The index of adiabatic expansion.
- E = Efficiency ratio.
- H = B.Th.Us. liberated on combustion of 1 lb. of fresh mixture.
- h = B.Th.Us. liberated on combustion of 1 lb. of cylinder contents, fresh and residuals.
- J = Joule's equivalent of heat, 1 B.Th.U. = 778 ft.-lb.
- R = Ratio of compression.
- k = Ratio of mean pressure of expansion to maximum pressure.
- r = Virtual compression-ratio in Appendix B.
- n = Any idea of expansion, of which γ is a special case.

In order that experimental results shall have value and enable us to form and test theories of action, it is necessary to have standards of performance with which to compare these results. In this Part the authors erect such standards of comparison and with them form a diagram upon which test-results can be readily examined.

Thermodynamic theory enables us to set up such standards for the four-stroke engine, and these standards would apply exactly to the two-stroke engine if in the charging of the cylinder there were no mixing of new and old contents until charging were complete, a condition which may be called perfect stratification.

On the other hand, we may assume a condition that as the new charge enters the cylinder it mixes perfectly with the old, and what passes out to exhaust is a true sample of the contents at the moment. In this case we get charging and temperature conditions differing from our four-stroke cycle ideal, and the authors will examine these. For reasons that will appear, they call this the Logarithmic Transfer assumption.

Beyond these two the authors have not been able to imagine any other form of performance which admits of analytical treatment and which is, therefore, useful as an ideal standard.

It appears to the authors advisable to derive these standards here, and they trust they will be pardoned for repeating much that is given in one form or another in text-books of thermodynamics.

The efficiency of the air standard is

$$E = 1 - R^{1-\gamma} \quad . \quad . \quad . \quad (1)$$

And if the heat liberated by combustion is H (B.Th.Us. per lb.) of fresh charge and the volume of 1 lb. of this charge is V_1 at the commencement of compression (Fig. 3), then the heat liberated per cubic foot of swept volume of cylinder* is the equivalent of

$$\frac{H\,J}{V_1} \text{ ft.-lb.}$$

and if we employ a cylinder of 1 sq. ft. area and 1-ft. stroke the mean effective pressure in lb. per sq. ft. is (*see* note*)—

$$\frac{E\,H\,J}{V_1} = \left(1 - R^{1-\gamma}\right)\frac{H\,J}{V_1}$$

mean effective pressure =

$$\left(1 - R^{1-\gamma}\right)\frac{H\,J}{144\,V_1} \text{ lb. per sq. in.} \quad . \quad (2)$$

Thus, the mean effective pressure for a given engine varies, ideally, directly as the heating value of the charge.

In Appendix B† it is shown that the effect of throttling is nearly the same as that of weakening the charge. It is to be borne in mind that in an actual engine throttling does have more effect as it gives a higher temperature of explosion and consequently greater radiation loss. Thus the expression of Equation (2) is justified as our standard.

It is clear that with no loss to exhaust, variation in the charge of a two-stroke engine is the same in effect as in a four-stroke engine as regards ideal efficiency and mean effective pressure. For if the temperature of the residuals has no effect in the one case it can have none in the other which differs only in degree. This may be shown in a similar working to Appendix A.† A divergence in practice may be noticed when the new charge is partially mixed with the old, giving some combustible and some incombustibly weak mixture which will be wasted. But this effect is probably small, since from the early practice of one of the authors it appears that mixtures too weak to ignite in the ordinary way will burn all right when another part of the charge is ignited and acts as a leader.

Logarithmic Transfer.

In place of imagining perfect stratification we can imagine that the contents of the chamber are at all times perfectly mixed, so that as an element of new charge enters an element of mixture passes to exhaust, this element being a true sample. If the whole system were at one temperature and there were at any time x volumes of fresh charge in the chamber of volume Q, then when δq entered, being fresh charge, δq will depart, being—

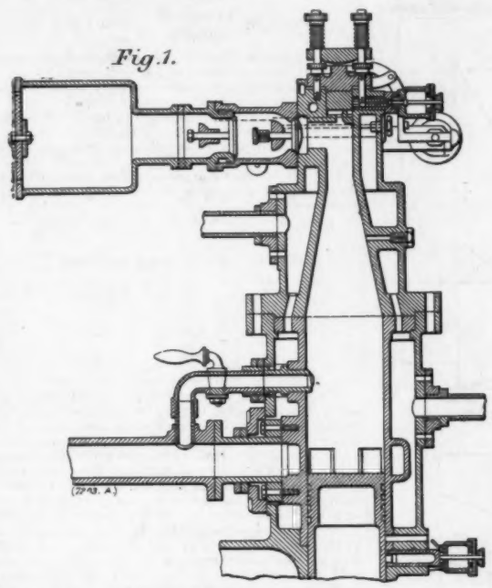


Fig. 1.

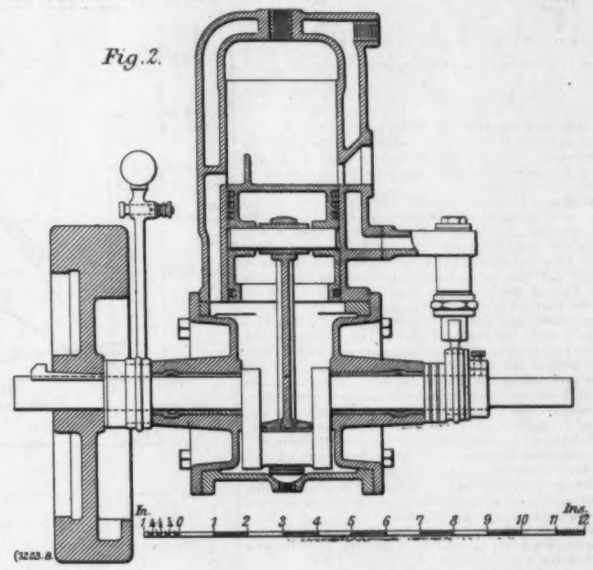


Fig. 2.

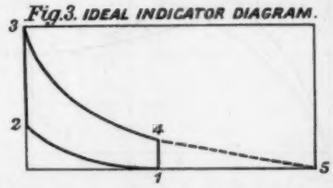


Fig. 3. IDEAL INDICATOR DIAGRAM.

Point 5, where Expansion reaches Atmospheric. Suffix 0 means Atmospheric Condition.

(7203.C.)

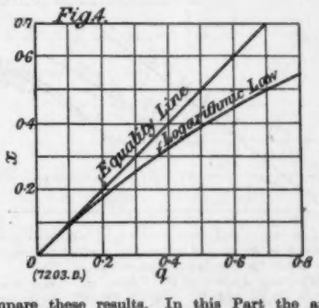


Fig. 4.

* The volume swept by the piston is under ideal conditions the true measure of the charge. It is shown in Appendix A that the temperature of the residuaries is without effect on the amount of the charge drawn in during induction, for to whatever extent the new charge is expanded by becoming heated by admixture with residuaries, to the same extent do the residuaries themselves undergo contraction.

† The Appendices will be published later.

$\frac{x}{Q}\,\delta q$ fresh charge.

The gain in fresh charge is therefore

$$\delta x = \left(1 - \frac{x}{Q}\right)\delta q$$

$$Q\frac{dx}{dq} = Q - x$$

$$\frac{dq}{Q} = \frac{dx}{Q - x}$$

$$\frac{q}{Q} = -\log(Q - x) + C$$

q	x	$\frac{x}{q}$
0.2	0.18	0.9
0.4	0.33	0.825
0.6	0.45	0.75
0.8	0.55	0.69
1.0	0.63	0.63

When Q is taken as unity C disappears and

$$q = \log\left(\frac{1}{1 - x}\right) \quad . \quad . \quad . \quad (3)$$

x being now the volume of new charge present in a chamber, *i.e.*, swept volume plus clearance of the cylinder, of unit volume, Fig. 4 on the preceding page shows the charge in the cylinder under this condition, compared with perfect stratification.

Now in this cold condition the mass proportion and the volumetric proportion always coincide, but if the residuals are hot the incoming element is heated and expands while the residuals cool and contract. The volumetric proportions are thus varied, but not the mass proportions. Hence, in mass proportions the action is the same hot or cold, always assuming equal specific heats for the two parties to the exchange.

We may state this again. Suppose the entering element to mix with the residual gas as laid down for the logarithmic law but without interchange of heat. Then any small part of the chamber will contain new and old gas in the proportions of a true sample. Now let them interchange heat and gain a uniform temperature. The new gas increases in volume in proportion as it heats up, and the old gas reduces in volume in proportion as it cools, and the total volume does not change; (P = const.) And also the relative masses in our small part of the chamber have not changed, so that the true sample passing out is now different in volumetric proportions, but the same in mass proportions as if the whole process took place at an even temperature.

Thus, if we know the value of γ and the heating power of our charge, we have standards of performance for the two ideal conditions.

First as regards the value of γ.

Petrol is a mixed fuel and variable, and for our purpose we must make an assumption as to its nature. Berriman* assumes it to average the same as octane, and this appears to be a fair average when we consider the probable actual contents.

Assuming this, Berriman shows that :—

1 lb. of petrol uses ideally 15 lb. of air.
1 cub. ft. of petrol vapour uses ideally 60 cub. ft. of air.

The combustion of octane

$$2\,C_8H_{18} + 25O_2 + \text{Nitrogen} = 16\,CO_2 + 18H_2O + \text{Nitrogen}$$

Atomic weights	228	800	2680	704	324	2680
Equivalent molecules present	2	25	94	16	18	94
		121			128	

Thus octane mixtures expand 5·8 per cent. on burning. But methane does not expand and benzene contracts, so we may neglect this. And the products of such combustion are by weight

19 per cent. carbon dioxide.
8·7 per cent. water.
72·3 per cent. nitrogen.

If we apply to this mixture the values for specific heat at constant volume given by Pye,† we obtain the mean values of specific heat from 200° F. to the actual temperature, and these are shown in Fig. 5. And we may deduce therefrom the actual specific heats which are again shown in Fig. 5. (*See* Appendix D.)

Again $S_p = S_v + C$ where C is the value in the expression P V = C T. For values in this we have the following densities (Appendix F).

	lb. per cub. ft. at 0 deg. C.	at 100 deg. C.
Air	0·0807 (1)	0·0591
Carbon dioxide ...	0·1234	0·0904
Nitrogen	0·0781	0·0572
Water	—	0·0378(2)

At standard pressure. (1) Smithsonian Physical Tables, (2) Ewing's Steam Engine.

	cub. ft.
Hence 19 lb. of carbon dioxide have a volume of	210
8 lb. of water have a volume of ...	230
72·3 lb. of nitrogen have a volume of	1,260
100 lb. of residue have a volume of	1,700

The density of the residue is 0·059 lb. per cub. ft. at 100 deg. C. or V = 17. And when T = 671 (F. abs.) V = 17 and P = 14·7 × 144 lb. per square foot. Hence $C = \frac{17 \times 14{\cdot}7 \times 144}{671} = 53{\cdot}5$ ft.-lb. or 0·0688 B.Th.U.

* *See* Proc. I.A.E., Vol. XIII., p. 100.
† See *The Automobile Engineer*, February, 1920.

And since $\gamma = S_p S_v$ we have its value. The working of this is shown in a Table in Appendix D.

Thus we obtain the value of γ for our expanding charge at different temperatures, shown in Fig. 5. It may similarly be shown that γ is not materially different for the unburnt mixture. Detail exploration of the cycle of operations will show us that the temperatures existing in expansion justify taking an average value of γ of 1·25. The mean temperature of expansion found by Mr. J. L. Napier* is about 3,000 Fahr. absolute, but for a fairly weak charge. This coincides with γ = 1·27. The authors, however, feel the more justified in their figure of 1·25 since an analysis of gas engine indicator diagrams gave this figure.

Further, we should find, in such exploration, that the error in assuming this value of γ throughout is negligible.

It is interesting to note that Messrs. Tizard and Pye†

Fig. 5. SPECIFIC HEAT OF PRODUCTS AT CONSTANT VOLUME.

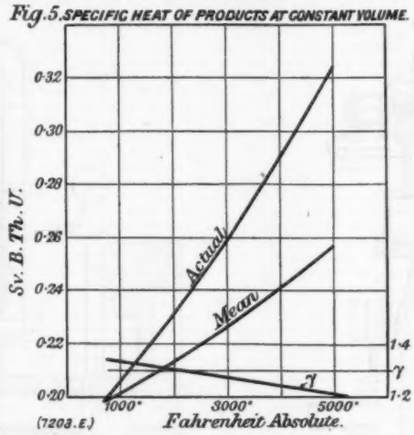


Fig. 6.

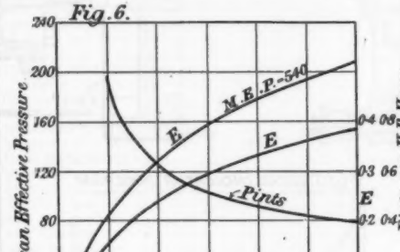
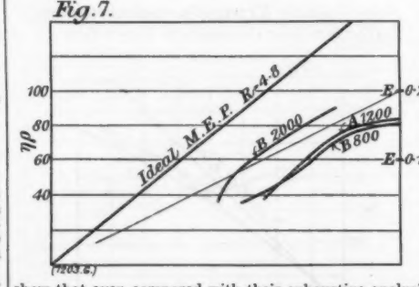


Fig. 7.



show that even compared with their exhaustive analysis this use of a mean value of γ is correct to one-half of 1 per cent. as for the expansion stroke.

The Heating Power of the Charge H.—We may take 20,000 B.Th.U. per lb. (= 15,560,000 ft.-lb. per lb.) as the heating value of petrol. Appendix E shows that from some points of view the exact accuracy of this figure is not important.

On our previous assumption 1 lb. of petrol forms 16 lb. of mixture giving H = 20,000/16 = 1,250 B.Th.U. per lb.

And the density of the mixture will be greater than that of air in the ratio of (16/15) × (60/61) = 1·05, and the density of air is 0·0765 lb. per cubic feet at 60 deg. Fahr.

∴ our mixture density is 0·08 lb. per cubic feet and

$$V_1 = 12{\cdot}5 \text{ cub. ft. per lb.}$$

Consequently, the B.Th.U. available per cubic foot $H/V_1 = 100$. Thus (Eqn. 2) our ideal mean effective pressure is

$$E\,(100\ J/144 = 540\ E = 540\left(1 - R^{1-\gamma}\right)$$

for a full charge, and proportionately less for fractional charges.

We can now draw a curve of ideal maximum mean effective pressure depending on the ratio of compression (Fig. 6).

Owing to the fact that we are using a liquid fuel, it is customary to measure efficiency in terms of pints of petrol per horse-power per hour, a custom strengthened by the existence of the flowmeter.

We have given 20,000 B.Th.U. per lb. for Pratts' 0·680 spirit, hence the heat value per pint is 20,000 × 1·25 × 0·68 = 17,000 B.Th.U. or 13,200,000 ft.-lb. per pint.

Representing $\frac{17,000}{2,550} = 6{\cdot}66$ h.p. hours,

or in lb. $\frac{13,200,000}{1,980,000} = 6{\cdot}66$ h.p. hours.

And a consumption of one pint per horse-power hour represents an efficiency of 1/6·66 = 0·15.

And the efficiency varies inversely as the consumption, hence

Pints per horse-power per hour = 0·15/E.

We can now write down the ideal consumption in pints per horse-power per hour of this fuel for different ratios of compression. (Fig. 6.)

Col. (3) of the table gives values based on a constant 500 as representing ηp in place of 540 giving mean effective pressure.

R	1 E=1−R^1−γ	2 M.E.P.=540 E	3 ηp=500 E	4 Pints per Horse-Power per Hour.
2	0·159	86	79·5	0·945
3	0·24	129·5	120	0·625
4	0·293	158	146	0·513
5	0·331	179	165	0·454
6	0·361	195	180	0·415
7	0·385	208	192	0·390

We have now determined our standards of performance. Incidentally, it may be noted that, in the ideal engine, the petrol consumption per horse-power per hour will not vary with the load. We may thus draw a diagram (Fig. 7) of which the ordinates are ηp and abscissæ B.Th.U. per cycle, and the ideal engine will give us a straight line law for its performance. Since such an engine is one of constant efficiency, this line is a line of constant consumption per horse-power per hour, it will be a straight line having a slope proportional to the efficiency. Every ray from the origin will represent a definite consumption of fuel or efficiency.

If now we test an engine, taking ηp and consumption readings, we can plot these on the diagram, each point being at the intersection of an ηp horizontal and a consumption ray. Thus we form a diagram always, of course, lying below the ideal line. The amount it lies below is the total loss from all causes, and the ratio of its ordinate to the ordinate of the ideal line is the relative brake efficiency of the engine. (For further discussion of this diagram, see Appendix F).

In Fig. 7 plottings are given for engines quoted by Pomeroy.* The letters refer to his engines similarly lettered, and the numbers give the revolutions per minute.

It is to be noticed that for its middle part the curve is approximately parallel to the ideal ray, showing that over this range the losses are constant. For the greater loads there is commonly greater loss.

(To be continued.)

* See *The Automobile Engineer*, December, 1911 February, 1912.
† See *The Automobile Engineer*, April, 1921.

CEMENT MANUFACTURE IN BRITISH MALAYA.—A committee dealing with the manufacture of cement in British Malaya state that there is available an unlimited supply of excellent material available for the local manufacture of a high-grade cement, yet not 10 per cent. of the requirements is locally produced. In view of the great demand, which will most certainly be maintained for some considerable period of years, it appears to the committee that the non-development of this industry is economically regrettable. In 1914 a cask of English Portland cement cost 4·26 dols. c.i.f. Port Swettenham. To-day the same cask would cost at least 13 dols. This might appear in itself sufficient inducement for private enterprise to take up and develop the local manufacture of cement, but unfortunately the cost of buying and setting up in Malaya a really efficient and economically-working plant is at the present time so great that any private company doing so would have to run the risk of finding itself seriously over-capitalised if and when prices revert to normal. The committee are of the opinion that Government should assist in the establishment of this industry on a firm economic basis. In this connection two facts have to be borne in mind. In the first place, small scale production is not economical. The only really economical plant is one capable of producing at least 30,000 tons to 40,000 tons per annum. In the second place, with a modern plant very little labour is required for cement manufacture. To encourage the local production of cement on a large scale, the committee, with one dissentient, suggested that the best means would be for the Government to undertake to fulfil all Government requirements of cement by local purchase from the company installing the necessary plant of approved capacity, at a guaranteed minimum price for cement of an approved standard of quality; and that the price should be one, variable with altering circumstances, and based on the actual cost of production plus a fair percentage for profit.

* See Proc. I.A.E., Vol. XIII, page 163.